

Phase II Remedial Investigations Report, Volumes I, II, III Sites P11/P13 and A12/P36/P37

Fort Devens Sudbury Training Annex, Maynard, Massachusetts

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U.S. Army Environmental Center
Aberdeen Proving Ground, Maryland 21010-5401

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Phase II Remedial Investigations Report, Volume I - General Sites P11/P13 and A12/P36/P37

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The United States Army Environment (RIs) at the Sudbury Training Annex, one RI conducted for Sites P11 and F	Maynard, Massachusetts. Five ass	signed sites were grouped into two R	orm two Remedial Investigations I clusters due to proximity, with				
This report is based on the results of field work E & E conducted from April 1993 through April 1994 at the Annex to evaluate the sites and incorporates the results of document searches, interviews, previous and ongoing environmental assessment efforts, and a review of previous studies produced by agencies of the United States Army and their contractors at the Annex.							
Volume I of this document presents of the Annex while it was government	at property previous investigations	conducted at the Annex, the type of	field work conducted, and the risk				
assessment approach used for these	sites. Volume I also includes a dis	cussion of background levels used in	evaluating each site.				
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Sudbury Annex Vol. I

Section No.: Preface

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PREFACE

This is Volume I of a four volume set that comprises the report of the remedial investigations (RIs) conducted at the Sudbury Training Annex of Fort Devens, Massachusetts. This volume serves to supplement the RIs contained in Volumes II and III by providing procedural and descriptive information common to the RIs and thus eliminating the need to repeat this information in each of the reports.

Volume II describes the RI, as well as the results and conclusions of the investigation, for a cluster of two sites: Site P11 - Building T405 Area and Site P13 - Massachusetts Fire Fighting Academy (MFFA). Volume III describes the RI, as well as the results and conclusions of the investigation, for a cluster of three sites: Site A12 - PCB Spill Remediation Area, Site P36 - Former Raytheon Building T104, and Site P37 - Building T106 UST.

Volume IV of this report set includes the appendices which present field notes, drilling logs, geotechnical data, geophysical investigation summaries, analytical qualification results, ecological investigation results, and other data produced during the RIs.

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Sudbury Annex Vol. I List of Acronyms

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LIST OF ACRONYMS

AA Atomic Absorption

AAL Acceptable Ambient Levels

AEHA U.S. Army Environmental Hygiene Agency

α alpha

AMSL Above Mean Sea Level

ARARs Applicable or Relevant and Appropriate Requirements
ARIEM Army Research Institute of Environmental Medicine

ASC Analytical Services Center (E & E)

AST Aboveground Storage Tank

ATSDR Agency for Toxic Substances and Disease Registry

AWQC Ambient Water Quality Criteria

BAF Bioaccumulation Factor
BEHP Bis(2-ethylhexyl)phthalate
BGS Below Ground Surface
BHC Benzenehexachloride

BNAs Base/Neutral/Acid Extractables

B(a)P Benzo(a)pyrene

BTEX Benzene, Toluene, Ethylbenzene, and Xylenes

β beta

BW Body Weight
CAA Clean Air Act

CAD Computer-Aided Design
CDIs Chronic Daily Intakes
CEC Cation Exchange Capacity

CEMEL Clothing Equipment Material Engineering Laboratory

CERCLA Comprehensive Environmental Response, Compensation, and Liability

Act of 1980

CFHA Capehart Family Housing Area
CHSO Corporate Health and Safety Officer
CLP Contract Laboratory Program

CNS Central Nervous System

COC Chain-of-Custody

COPCs Contaminants of Potential Concern

cPAHs Carcinogenic Polynuclear Aromatic Hydrocarbons

CRLs Certified Reporting Limits

CWA Clean Water Act cm/sec Centimeters per Second

DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
DEC Digital Equipment Corporation

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delta

DERP Defense Environmental Restoration Program

DoD U.S. Department of Defense DOT

U.S. Department of Transportation

DOOs Data Quality Objectives

ECAOs Environmental Criteria Assessment Office

ED **Exposure Duration**

E&E Ecology and Environment, Inc.

EM Electromagnetics

EMO Environmental Management Office (Fort Devens)

EP Equilibrium Partitioning

EPA U.S. Environmental Protection Agency

EPCs Exposure Point Concentrations

ERL Effects-Range Low **ERM** Effects-Range Median

Environmental Science and Engineering Laboratories, Inc. **ESE ETC** Environmental Testing and Certification Corporation

FDA Food and Drug Administration

FEL Food Experiment Laboratories (Natick Laboratories)

FEMA Federal Emergency Management Agency

FIT Field Investigation Team

FOCUS Families Organized to Clean-up Sites

FORSCOM U.S. Army Forces Command

FS Feasibility Study

Grams

GC Gas Chromatography

Y gamma

GI Gastrointestinal gpm Gallons per Minute Ground Penetrating Radar **GPR**

GW Groundwater

GZA Goldberg Zoino and Associates

HA Health Advisory - HASP Health and Safety Plan

HEAST Health Effects Assessment Summary Tables

HEPA High-Efficiency Particulate Air HHEM Human Health Evaluation Manual

HI Hazard Index HO **Hazard Quotient**

IARC International Agency for Research on Cancer

IQ Intelligence Quotient IR **Ingestion Rate**

IRDMIS Installation Restoration Data Management Information System

IRIS Integrated Risk Information System IRP Installation Restoration Program

Kilogram kg

LADIS Lifetime Average Daily Intakes

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LD50

Lethal Dose to 50 Percent of Population

LEL

Lowest Observed Effect Level

LFS LOAEL Leupold Forestry Service

MABSP

Lowest Observed Adverse Effect Level Maynard Ammunition Backup Storage Point

MADEOE

Massachusetts Department of Environmental Quality and Engineering

MA/CWA

Massachusetts/Clean Water Act

MA SMCL

Massachusetts Secondary Maximum Contaminant Level

MBSA **MCLs MCLGs** Maynard Back-up Storage Area Maximum Contaminant Levels Maximum Contaminant Level Goals Massachusetts Contingency Plan

MCP **MDEP**

Massachusetts Department of Environmental Protection

MA DEOE

Massachusetts Department of Environmental Quality and Engineering

MC

Methylene Chloride or Dichloromethane Methyl Ethyl Ketone or 2-Butanone

MEK **MEP**

Master Environmental Plan

MF

Modifying Factor

MFFA

Massachusetts Fire Fighting Academy

MMCLs

Massachusetts Maximum Contaminant Level

m

Meter

mg

Milligrams Micrograms per Deciliter

 $\mu g/dL$ ml

Milliliter

mmhos/m

Millimhos per Meter

MOE **MOTS** Ontario Ministry of the Environment Maynard Ordnance Test Station

MOAPiP

Master Quality Assurance Project Plan

MREs MRLs Meals Ready to Eat

MS/MSD

Method Reporting Limits Matrix Spike/Matrix Spike Duplicates

 $\mu g/g$

Micrograms per Gram

 $\mu g/L$

Micrograms per Liter

NAAOS

National Ambient Air Quality Standards

NARADCOM

U.S. Army Natick Research and Development Command

NCO NCP

Non-Commissioned Officer National Contingency Plan

NDIR.

Non-Disperse Infra-Red Spectroscopy

NERI

Northeast Research Institute, Inc.

NESHAPs

National Emission Standards for Hazardous Air Pollutants

NFA

No Further Action

NFADD

No Further Action Discussion Document

NHESP

Natural Heritage and Endangered Species Program (Massachusetts)

NOAA

National Oceanic and Atmospheric Administration

NOAEL

NPL

No Observed Adverse Effect Level

National Priorities List

NTU

Nephelometric Turbidity Unit

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List of Acronyms

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NWI National Wetlands Inventory

NYSDEC New York State Department of Environmental Conservation **OHM**

OHM Remediation Services Corporation, A Subsidiary of OHM

Corporation

ORSG Office of Research and Standards Guidance (Massachusetts)

OSHA Occupational Safety and Health Administration

OVA Organic Vapor Analyzer PA Preliminary Assessment **PACE** PACE Incorporated PAE Phthalic acid esters

PAH Polynuclear Aromatic Hydrocarbons or Polycyclic Aromatic

Hydrocarbons

PARCC Precision, Accuracy, Representativeness, Comparability, and

Completeness

PCB Polychlorinated Biphenyl

PCE Tetrachloroethene or Perchloroethene

PHC Petroleum Hydrocarbons PID Photoionization Detector **POLs** Petroleum, Oil, or Lubricants

ppb Parts per Billion

PPE Personal protective equipment

ppm Parts per Million

PRP Potentially Responsible Party

PVC Polyvinyl Chloride QA Quality Assurance

QAPjP Quality Assurance Project Plan

QC Quality Control

RAGS Risk Assessment Guidance for Superfund

RAS Routine Analytical Services RBA II Rapid Bioassessment Protocol II **RBC** Risk-Based Concentration

RCRA Resource Recovery and Conservation Act

RfD: Reference Dose RI Remedial Investigation

RME Reasonable Maximum Exposure **RPD** Relative Percent Difference

RU Risk Update

SAS Special Analytical Services SCS Soil Conservation Service SDIs Subchronic Daily Intakes **SDWA** Safe Drinking Water Act

SED Sediment SF Slope Factor SI Site Investigation SM Scanner Magnetrometric

Secondary Maximum Contaminant Level SMCL

SOW Scope of Work

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SQC Sediment Quality Criteria
SSI Supplemental Site Investigation
STP Massachusetts State Planar

SUF Site Use Factor
TAL Target Analyte List
TBC To Be Considered

TBV Toxicity Benchmark Value

TCA Trichloroethane TCE Trichloroethene

TCL Target Compound List

TEPS Total Environmental Program Support
TIC Tentatively Identified Compound

TOC Total Organic Carbon

TPHC Total Petroleum Hydrocarbons
TRC Technical Review Committee
TRV Toxicity Reference Values
TSCA Toxic Substances Control Act
TSS Total Suspended Solids
UF Uncertainty Factor

USAEC United States Army Environmental Center

USAF United States Air Force

USATHAMA United States Army Toxic and Hazardous Materials Agency

USCS Unified Soil Classification System
USDA United States Department of Agriculture

USDOHHS United States Department of Health and Human Services

USDOI United States Department of the Interior USFWS United States Fish and Wildlife Service

USGS United States Geological Survey
UST Underground Storage Tank
UXO Unexploded Ordnance
VOA Volatile Organic Analysis
VOC Volatile Organic Compound
WHO World Health Organization
WQC Water Quality Criteria

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1. INTRODUCTION

Under Total Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012, Delivery Order No. 0004, Phase II Site Investigation, Remedial Investigation of Sudbury Annex, the United States Army Environmental Center (USAEC) tasked Ecology and Environment, Inc. (E & E) to perform two Remedial Investigations (RIs). The five assigned sites were grouped into two RI clusters due to proximity, with one RI conducted for Sites P11 and P13, and one RI conducted for Sites A12, P36, and P37. Investigation activities were carried out at the Fort Devens Sudbury Training Annex (the Annex), Massachusetts. Figure 1-1 depicts the location of the Annex in Massachusetts. Figure 1-2 shows the location of the two RI clusters.

The five sites grouped together for the two RIs are a subset of 70 Phase I Site Investigations (SIs) originally identified or investigated by OHM Remediation Services, Inc. (OHM) between 1990 and 1992. Subsequently, in 1993, E & E conducted Phase II SIs at 38 sites. On the basis of the Phase II SI field results, these five sites were separated from the SI sites and grouped into two RIs. In 1994, additional field work was conducted to support the development of human health and ecological risk assessments for the RI sites. The Phase II SIs are discussed in a separate report (E & E 1994b).

Site activities have been conducted in accordance with the Inter-Agency Agreement between the United States Army and the United States Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986, as well as the National Contingency Plan (NCP). In 1990, the Annex was placed on the National Priorities List (NPL), the list of sites to be investigated under CERCLA (Superfund). The EPA analysis of the Annex was based in part on ongoing Army environmental studies under the Defense Environmental Restoration Program.

This report is based on the results of field work E & E conducted from April 1993 through April 1994 at the Annex to evaluate the sites assigned under Phase II, and incorporates the results of document searches, interviews, previous and ongoing environmental assessment efforts, and a review of previous studies produced by agencies of the U.S. Army and their contractors at the Annex. E & E evaluated each site based on the results of the current as well as previous investigative activities undertaken to characterize it as a potential contaminant source or as an area affected by contaminant movements.

Volume I of this document presents general information about the Annex, including information on general physical characteristics, historic uses of the Annex while it was government property, previous investigations conducted at the Annex, the type of field work conducted, and the risk assessment approach used for these sites. Volume I also includes a discussion of background levels used in evaluating each site.

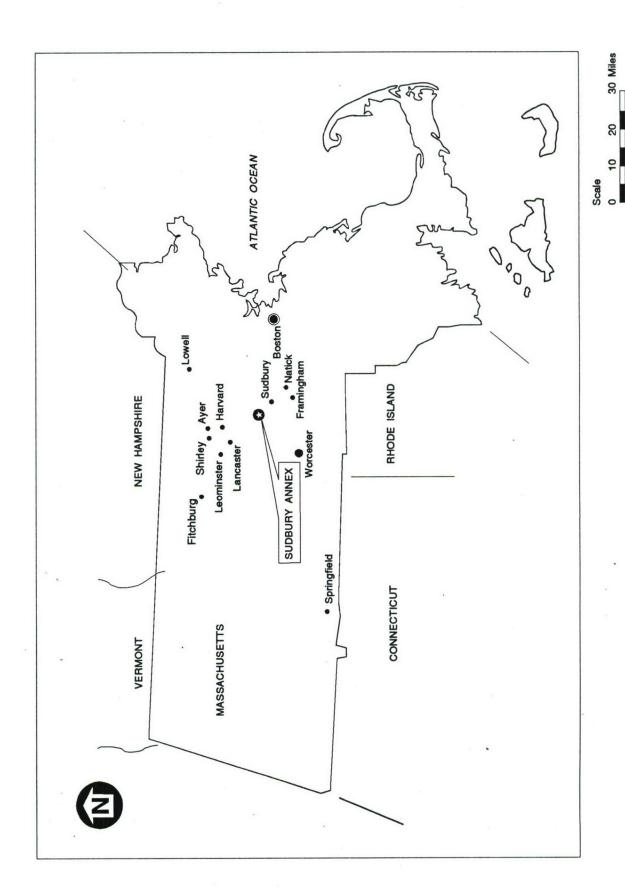


Figure 1-1 LOCATION OF FORT DEVENS SUDBURY TRAINING ANNEX IN MASSACHUSETTS

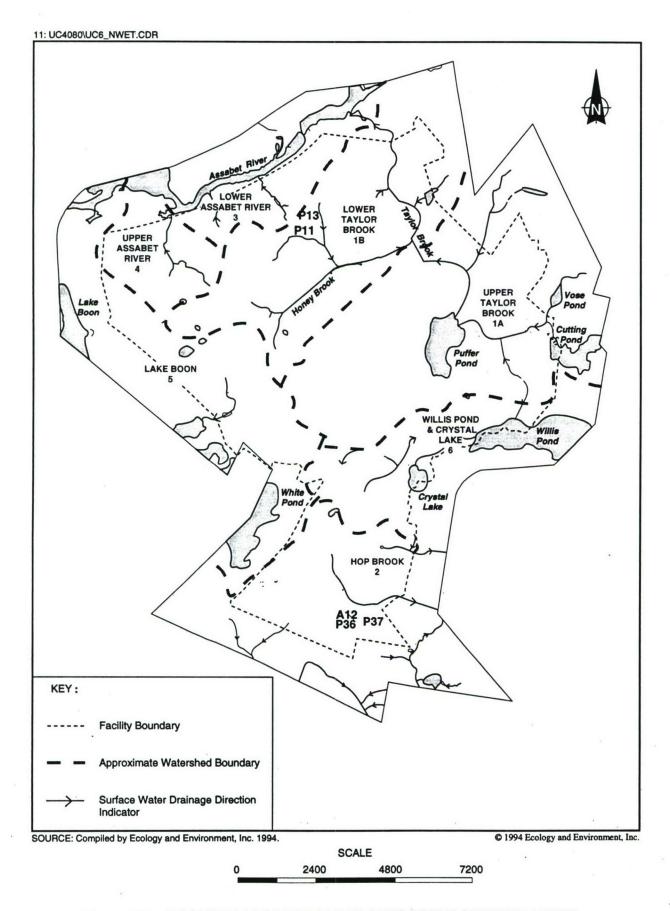


Figure 1-2 LOCATION OF INVESTIGATION SITES AT THE SUDBURY ANNEX

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Volume II presents the RI report for Sites P11 and P13. Volume III presents the RI report for Sites A12, P36, and P37. Conclusions for each RI are presented at the end of each volume. Volume IV consists of all supporting appendices.

1.1 BACKGROUND AND AUTHORITY

The Army assembled the Annex property between 1939 and 1942, at which time it became fully functional as an Army installation. During its history, from 1942 until today, the Annex has had several names and has had multiple uses, including ammunition storage, ordnance research and development, laboratory research, field testing of equipment, railroad operations, troop training, and possible burial and disposal of cloth, food, and chemicals.

In 1978, the Department of Defense (DoD) established the Installation Restoration Program (IRP). Under the IRP, the DoD sought to identify, investigate, and clean up contamination from hazardous substances at Federal facilities. Environmental investigations were started at the Annex in 1980 under the IRP in order to address the potential for environmental impacts from past land uses.

As a first step in the program, the USAEC (formerly USATHAMA--the United States Army Toxic and Hazardous Materials Agency) conducted a preliminary site assessment, which primarily consisted of a detailed records search. The 1980 initial site assessment report indicated that certain portions of the Annex may have been contaminated with the following:

- explosive residues,
- - laboratory quantities of chemical wastes,
- petroleum, oil, or lubricants (POLs), and
- other toxic or hazardous materials.

USAEC, in accordance with the IRP, contracted the services of Dames and Moore of Bethesda, Maryland, to conduct an RI at the Annex. The results were presented in the 1986 Final Remedial Investigation Report by Dames and Moore (Dames and Moore 1986b).

Prior to final publication of the RI report, the EPA Region I, Waste Management Division, contracted the services of NUS Corporation of Bedford, Massachusetts, to conduct a preliminary assessment (PA) of the Annex under the Superfund Field Investigation Team (FIT) program. The PA included a review of Dames and Moore's final RI report. On the basis of the PA, the EPA instructed the FIT to conduct an SI of the Annex.

On 29 January 1987, the Annex was classified as a Federal facility under the jurisdiction, custody, and control of the DoD, within the meaning of Executive Order 12580, 52 Federal Regulations 2923, and within the meaning of the Defense Environmental Restoration Program (DERP), 10 U.S.C., Section 2701 et seq. The Annex is, as a consequence, participating in the DERP. While the objectives of the IRP and DERP are essentially the same, the funding sources are different; IRP funds are generally used for active facilities and DERP funds are generally used for inactive facilities. The Master

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Environmental Plan (MEP), authored by OHM in 1992 (OHM 1992) and updated by E & E in 1993 (E & E 1994a), is consistent with the intent and objectives of the IRP. Annually updated, the MEP is a key element in the attainment of DERP goals.

On May 26, 1987, NUS Corporation completed an SI report on the Annex for EPA Region I. The EPA determined that the Annex should be added to the NPL, and it was included in the EPA NPL Update No. 9 in the 14 July 1989 Federal Register (USEPA 1989f). On 21 February 1990, the Annex was placed on the NPL.

1.2 OBJECTIVES

Delivery requirements for the E & E Phase II SI/RI project were outlined in the Scope of Work (SOW). The sites to be investigated as part of the E & E Phase II effort were selected by the USAEC in an ongoing process that took into account recommendations made by OHM in their Final Site/Remedial Investigation Report (OHM 1994) and the results of discussions with the Technical Review Committee (TRC), including the Fort Devens Environmental Management Office (EMO). Two RIs were conducted on a total of five sites for which risk characterization was recommended to assess residual risks posed by contaminants of concern found at these sites. The type of field investigation undertaken at each site was tailored according to recommendations and information available on the site and on past practices in the site area. The objective of the site characterization effort was to collect sufficient information on each site to fully characterize the nature and extent of contamination and to support the baseline human-health and ecological risk assessments.

Investigation activities involved reviewing existing data, evaluating current site conditions, establishing data quality objectives, and performing field sampling and analysis. Objectives included the following:

- · describing physical and environmental conditions at the sites;
- determining the nature, extent, and source (as possible) of hazardous substances and/or wastes present at the site;
- defining the geologic and hydrogeologic characteristics of the site that may affect contaminant migration and assess possible migration off-site;
- presenting information on contaminant concentrations, potential migration pathways, fate and transport of contaminants found, methods of contaminant release, sources of hazardous substances (as possible), and data summaries;
- using the analytical data to perform baseline human-health and ecological risk assessments; and,

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• using the results of the risk assessments and applicable or relevant and appropriate requirements (ARARs) to identify preliminary remedial goals, if warranted.

1.2.1 Data Requirements

For the Annex project, the intended uses of the data generated through sampling and analysis are to allow for accurate site characterization and baseline risk assessments. If the results of the risk assessments indicate that unacceptable risks exist at the site, then the data will be used to outline options for preliminary remediation goals for consideration in the Feasibility Study (FS), which is the next stage in the remediation process.

1.2.2 Data Quality Objectives

Data Quality Objectives (DQOs) were developed for the Annex sites to ensure that data collected during the investigation will be of sufficient quality to support decision-making. Site-specific questions such as why data are to be collected, how data will be used, and how much are required were addressed while developing the DQOs. In addition, the required data quality was addressed to indicate the magnitude of error that could be tolerated by the data user. Tables and figures in this section present the results of this evaluation.

This subsection of the report focuses on the objectives of the investigation while the remaining subsections of Section 1 describe the capabilities of the sampling and analytical teams. Professional judgement is used to ensure that data collected meet the objectives of the risk assessments while, at the same time, not incurring excessive costs. Compromises between DQOs and these capabilities are addressed within the framework of sound fiscal management for the Annex. Overall, the rationale and justification for each data-collection activity, as well as alternative approaches to meeting project objectives, are provided in the work plans and sampling plans.

DQOs are qualitative or quantitative statements developed by the data user to specify the quality of data needed from a particular data collection activity to support specific decisions. DQOs represent the starting point in the design of a given study. The process of developing DQOs helps to identify critical data points and eliminate data points with limited applications, and thereby promote overall fiscal accountability. In addition, the DQO development process matches sampling and analytical capabilities to the data targeted for specific uses and ensures that the quality of the data do not overestimate or underestimate project requirements. The DQO development process is outlined in EPA guidance publication, *Data Quality Objectives for Remedial Response Activities*, EPA/540/G-87/003/4, March 1987 (USEPA 1987).

EPA has identified five general levels of analytical data quality as being potentially applicable to site investigations conducted under the CERCLA. These levels are summarized as follows:

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- Level I Field Screening: This level is characterized by the use of portable instruments that can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. Data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations.
- Level II Field Analysis: This level is characterized by the use of portable analytical instruments that can be used on site or in mobile laboratories stationed near a site (close-support labs). Depending upon the types of contaminants, sample matrix, and personnel skills, qualitative and quantitative data can be obtained.
- Level III Laboratory Analysis: This level uses methods other than the Contract Laboratory Program (CLP) Routine Analytical Services (RAS). This level is used primarily in support of engineering studies using standard EPA-approved procedures. Some procedures may be equivalent to CLP RAS, without the CLP requirements for documentation.
- **Level IV CLP RAS:** This level is characterized by rigorous quality assurance/quality control (QA/QC) protocols and documentation, that provide qualitative and quantitative analytical data.
- Level V Non-Standard Methods: This level includes analyses which may require method modification and/or development. CLP Special Analytical Services (SAS) are considered Level V.

For the Annex, field measurements (such as pH, temperature, conductivity, and readings from an organic vapor analyzer (OVA) or HNu photoionization detector (PID) and MSA Model 260 0₂/Explosimeter will constitute Level I field analytical data. More sophisticated instrumentation (such as Photovac 10S 50, OVA in gas chromatography (GC) mode, X-MET 880) used for on-site analysis of volatiles, metals, etc., will be considered as Level II analytical data supported by more extensive logbook documentation, calibration, and quality control.

Analyses for Target Compound List (TCL) organics, Target Analyte List (TAL) metals, and explosives will be considered approximately equivalent to EPA analytical support Level IV quality data. That is, all data will be generated according to USAEC guidelines, the same level of quality and documentation as Region I CLP protocol. Appendix D contains a detailed discussion of such revisions. Table 1-1 presents a list of various analyses and data uses according to the five levels of analytical data quality described above. Historical USAEC precision and accuracy data will be used as the basis for developing acceptance criteria for assessing the precision and accuracy of generated data. The historical data will be obtained from the Installation Restoration Data Management Information System (IRDMIS)

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	Table 1-1	
	EPA GENERAL LEVELS OF ANALY	TICAL DATA QUALITY
Level	Data Uses	Type of Analysis
I	Site characterization Monitoring during implementation of remedial action.	Total organic/inorganic vapor detection using portable instruments. Field Test Kits.
П	Site characterization Evaluation of alternatives. Monitoring during implementation of remedial action.	Field analysis using sophisticated portable instruments or mobile lab. Variety of organics by Gas Chromatography
		Identification only tentative, but analyte- specific. Detection limits vary from low parts per million to low parts per billion.
Ш	Risk Assessment Potentially-responsible party (PRP) determination. Site characterization. Evaluation of alternatives. Engineering design of remedial action. Monitoring during implementation of remedial action.	Analysis performed in off-site lab. Organics/inorganics using EPA procedures other than CLP can be analyte-specific. Resource Conservation and Recovery Act (RCRA) characteristic tests.
IV	Risk Assessment PRP Determination. Evaluation of Alternatives. Engineering design of remedial action.	CLP routine analytical services. TCL organics by GC/MS, TAL metals by AA, Inductively Coupled Plasma (ICP). Low parts per billion detection limit. Rigorous QA/QC protocols and documentation.
V	Risk Assessment Engineering design of remedial action. PRP determination.	Non-conventional parameters. Method-specific detection limits. Modification of existing methods; method development. Appendix IX 40 CFR 264 parameters.

Source: Ecology and Environment, Inc. 1994.

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database prior to the start of the sampling and analytical program. Several physical and water quality parameters will be evaluated using standard EPA methods or USAEC-validated methods. The data generated will be comparable to EPA Level III data.

Data assessment procedures involve the application of precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters to determine whether DQOs have been achieved. PARCC parameters are integrated throughout the Quality Assurance Project Plan (QAPjP) and applied throughout the data collection process (E & E 1994f). In this section, qualitative statements regarding PARCC will be summarized for each data collection activity. PARCC parameters are briefly defined below:

- **Precision:** a measure of the variability in measurements on the sample compared to the average value. Reported as relative percent difference (RPD), the difference divided by the average of two positive samples results. The overall precision is a mixture of sampling and laboratory variability. Laboratory duplicate and field duplicate analyses are used to determine precision, with laboratory duplicate RPDs providing a measure of analytical precision and field duplicate RPDs providing a measure of overall precision.
- Accuracy: the degree of agreement of a measurement with an
 accepted reference or "known" value, which is a measure of bias of
 the system. This "known" can take the form of EPA or National
 Institute of Standards and Technology-traceable standards, laboratoryprepared solutions of target analytes, or solutions of surrogate
 compounds spiked into each sample. Accuracy is calculated in terms
 of percent recovery, correcting for analytes/compounds present in the
 original sample, if necessary.
- Representativeness: the degree to which sample data represent the
 actual situation at the sampling site. Representativeness is
 maximized by proper selection of sampling locations and collection
 of a sufficient number of samples. It can be assessed quantitatively
 by evaluation of field duplicate RPD and qualitatively by evaluation
 of the degree of homogeneity of the site and of any one sample from
 the site.
- Completeness: a measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under normal operating conditions.
- Comparability: expresses the confidence with which one set of data
 can be related to another. Quantitatively, comparability can be
 assessed in terms of precision and accuracy of two sets of data.
 Qualitatively, data subjected to strict QA/QC procedures will be
 deemed more reliable than data obtained without the use of these

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procedures. To maintain comparability, proper sampling methods, chain-of-custody procedures, EPA-approved analytical methods, and strict QA/QC procedures provide the basis for uniformity in all data collection and analysis activities.

1.3 PROJECT APPROACH

The field activities were designed to address the possible contamination and potential migration of hazardous substances from the five assigned RI sites. Because of the size of the Annex (approximately 4.3 square miles) and the large number of scattered sites of suspected waste disposal, it was decided as part of the RIs and SIs to develop an overall approach to assessing the possible impacts of Annex sites on the surrounding environment, in addition to conducting the more specific site evaluations required.

The Army's use of the Annex for various purposes over the past 50 years has been considered to be a primary potential source of pollution. Other institutions such as the Massachusetts Fire Fighting Academy (MFFA), and even the general public, have added to possible sources of pollution on and adjoining the area. The question of overall impact was therefore best addressed by determining which media (soil, air, groundwater, surface water, and sediment) were contaminated.

This approach led to dividing the Annex into seven distinct watersheds, so that each site could be evaluated for its potential as a contaminant source or repository, as well as its potential for impact on neighboring sites, on the watershed in which it is located, on the Annex as a whole, and on surrounding areas.

The most important mobile material at the Annex is water, and this is the medium that may carry contamination off the Annex, and transport contaminants within the Annex from soil to groundwater, from soil to surface water, from groundwater to surface water, and from within a specific site to more widely exposed populations and to the environment.

Thus the cumulative impacts of all the sites within a given watershed tend to be concentrated in the sediments within the surface water draining the watershed and in the surface water itself, and can affect the health and diversity of the biota living in the surface water when compared to appropriate background locations.

The climate, geology, and hydrology of the Annex, while not studied in exhaustive detail, are all well enough known to permit considerable confidence in determining the overall flux of water within the Annex, its volume, its origin, and its destination. This information allowed the selection of a strategy to both characterize the impact of individual sites and to determine which sites may have joint cumulative impacts on any specific body of water, such as a stream, pond, or river.

The watershed approach to investigation of potential contamination at the Annex entailed a review of possible contamination linked to specific sub-zones within the Annex, thereby providing a further level of detail and a new reference measure for the possible

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impacts of the Annex on the surrounding environment or the potential human health risks through access to the Annex.

The results of watershed assessments are included in the Phase II Site Investigation Report for the Annex (E & E 1994b). Although these watershed assessments are not discussed in this report, the results of the watershed assessments were used to help understand the impact of the five RI sites on the surrounding parts of the Annex.

Specific techniques used to investigate sites within the seven watersheds designated at the Annex include the following:

- A facility-wide groundwater model was prepared as a 3-dimensional flow model using MODFLOW, a United States Geological Survey (USGS) model, which can be used to model volumes of groundwater flow off the sites through various media, and establish relative proportions of flow. It also provides confirmation of probable mass transport of contaminants from specific sites to supplement individual site studies.
- Surface geophysics were employed, such as seismic, ground penetrating radar (GPR), and electromagnetic conductivity (EM), to help define the subsurface conditions or the extent of disposed materials.
- Test pits were excavated to assess anomalies and areas of concern.
- Borings were installed to collect subsurface samples and to estimate the horizontal and vertical extent of soil contamination.
- Monitoring wells were installed providing a hydrological framework.
 The wells were sampled to determine groundwater quality and extent of contamination.
- Depth-to-water measurements were taken on new and existing monitoring wells to provide data on the water elevation and the groundwater flow direction.
- Surface water measurements taken during the same time as the monitoring well measurements provided data for the groundwater flow model.
- Slug tests determined the hydraulic conductivity of the overburden and the rate of groundwater migration, and assessed the feasibility of groundwater remediation.

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- Building wipe samples were collected to assess potential residual contamination within one building.
- Surface soil samples were collected to assess the extent of contamination and potential impacts on human health and ecology.
- Surface water and sediment samples were collected to determine the extent of contaminant migration by surface runoff, to drainage areas, streams, and ponds, to further characterize contaminant migration.
- Off-site soil samples were collected to establish a background level for comparison.
- Surveys of stream benthic communities, wetlands, terrestrial fauna and flora, and pond/lake communities, provided data on current ecological conditions.
- Bioaccumulation of metals and pesticides was studied in Puffer Pond and in a comparable off-site pond.

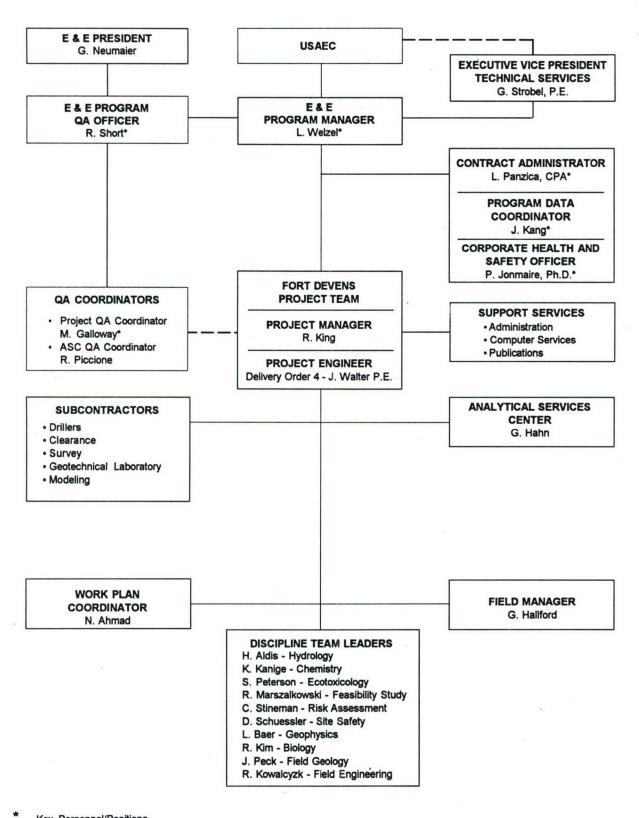
Previous soil gas surveys and field instrument measurements did not imply that volatilization and air contamination was of concern at the Annex, and therefore additional air investigation was not undertaken.

1.4 PROJECT ORGANIZATION AND RESPONSIBILITY

1.4.1 E & E Structure

E & E organizes and implements its management functions based on a matrix corporate structure. E & E provides technical services/administrative support within a permanent corporate structure and performs delivery order assignments as specifically tailored projects. Each of the firm's operating divisions is headed by an executive vice president. The Program Manager for this contract reports to the Executive Vice President-Technical Services, Mr. G. Strobel, P.E. Within the contract organization, the Project Manager reports to the Program Manager. Figure 1-3 presents the organization structure that E & E uses to manage Delivery Order No. 0004 and also indicates the key individuals selected for Delivery Order No. 0004, from the Program Manager through the various team leaders. E & E identified team leaders in the following functional areas critical to the implementation of this delivery order: RI leader, geology, chemistry, ecology, risk assessment, and site safety. Key support personnel were identified in the areas of field geology, ecology, and field safety. Figure 1-3 also identifies, by function, other support personnel that will be used for this delivery order.

E & E used subcontractors to support specialized work elements of Delivery Order No. 0004. They included subcontractors for surveying, specialty analytical work, drilling, and the development of the hydrogeological model.



Key Personnel/Positions

Figure 1-3 PROJECT ORGANIZATION

Sudbury\UC6012.PM4

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1.4.2 Client Organization

E & E receives direction through the USAEC Contracting Officer's Representative and coordinates field activities at the Annex with the Fort Devens Environmental Management Office. E & E's principal project contact at USAEC is Mr. Dean Hutchins. He coordinates the project technical activities and provides day-to-day technical oversight of the project. E & E's contact at Fort Devens is Mr. Tom Strunk. He serves as the principal contact between USAEC and Fort Devens and coordinates the Fort's contact with the representatives on the Technical Review Committee. E & E's Project QA Officer coordinates the submission of analytical data with Mr. Ivan Sosa, the USAEC Project Chemist. Mr. Sosa is responsible for monitoring the operation of the laboratory according to the approved QA Program (E & E 1993) and providing formal notification to E & E of any unapproved deviations from the program.

This delivery order was awarded by the Chemical and Biological Defense Agency, Procurement Directorate, AMSCB-PCD, APG, MD, 21010-5423 for USAEC. Ms. Angie Sawyer is the Contracting Specialist for this delivery order. Additional USAEC project support is provided by the technical services branch and includes the following:

Mr. Larry Nutter

USAEC Geologist

Mr. William P. Houser -

USAEC Safety Officer

Ms. Lori Summers

USAEC Public Affairs

1.5 REPORT ORGANIZATION

This RI Report is presented in four volumes: Volume I discuss the project's background, objectives, organization, and approach; characteristics and use history of the Annex; previous investigations; field investigation and analytical procedures; and background levels. Volume II - Remedial Investigations of Sites P11/P13 - and Volume III - Remedial Investigation of Sites A12/P36/P37 - presents the history, field work, findings, and recommendations for the two RI subject areas. Volume IV (Appendices A through P) presents the reports and data collected as a result of field work performed at the individual sites and from broader surveys and computer modeling at the Annex. These technical field reports can be used to support and provide greater detail about the information given for sites in earlier sections. The analytical data are in electronic format and are submitted with this report on diskettes containing USAEC's IRDMIS Level 3 analytical data. These diskettes can be found in Appendix M.

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2. GENERAL ANNEX CHARACTERISTICS

2.1 HISTORY OF SUDBURY ANNEX

The land use history of the area currently known as the Annex has been researched by the USAEC and its contractors. E & E presents the information gathered from this research in Section 3 of the 1994 Draft Master Environmental Plan (E & E 1994a). A general information summary is repeated here. For more complete information, please refer to the MEP.

The bulk of the research discusses the Annex's history after acquisition of the land by the U.S. Government in the early 1940s. Information tied to specific activities at individual sites has been included in the historical sections of the relevant areas.

In 1942, the U.S. government established the Annex to store surplus ammunition for the World War II war effort and named it the Maynard Ammunition Backup Storage Point (MABSP). In 1946, the facility became part of Watertown Arsenal and was subsequently referred to as Watertown Arsenal (Maynard). The Annex continued to be used as a storage depot until 1950, when it was transferred to the First Army and for two years became a storage and training subinstallation of Fort Devens. In 1952, the facility was renamed the Maynard Ordnance Test Station (MOTS) and kept that name through at least 1957. From 1952 to 1957, the Annex was principally used for ordnance research and development activities under the Chief of Ordnance.

In 1958, control of the Annex was transferred to the Quartermaster Research and Engineering Center at Natick. While troop training activities continued, the Annex was now also available for the field testing of experiments developed in the laboratories at Natick. Other agencies and or operators were also granted permission to use the Annex for a variety of activities primarily related to materials testing and personnel training. In 1962 the Capehart Family Housing Area (CFHA) was established and constructed by Natick Laboratories to house its employees. The designation for the Quartermaster Research and Engineering Center was changed to Natick Laboratories in 1962 and to Natick Research and Development Command (NARADCOM) in 1976. NARADCOM maintained overall control of the Annex until 1982.

Fort Devens, located some 15 miles to the northwest of the Annex, received custody of the entire Annex in 1982. Fort Devens' current mission is to command and train the duty units and to support the U.S. Army Security Agency Training Center and School, the U.S. Army Reserves, the Massachusetts National Guard Reserve Officer Training Programs, and the Air Defense sites in New England. Under Public Law 101-510, the Defense Base Closure and Realignment Act of 1990, Fort Devens has been selected for cessation of operations and closure by the end of 1995. The Annex has been used primarily for personnel training

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activities for active duty Army units, for the Army Reserve, as well as for Army and Air National Guard troops. Currently, the Annex is a part of Fort Devens and includes several areas actively in use.

2.2 FACILITY PHYSICAL SETTING

The facility physical setting is discussed in this section. An understanding of the physical setting of the facility can be obtained by considering factors that include location and geography, climate, geology, hydrogeology, demography and land use, facility ecology, as well as soils, surface water and drainage, and groundwater use and quality.

2.2.1 Location and Geography

The Annex is located 20 miles west of Boston, one mile south of Maynard, and two miles northwest of the Town of Sudbury, in Middlesex County, Massachusetts. The installation includes portions of the towns of Maynard, Hudson, Marlborough, Stow, and Sudbury.

The installation covers approximately 4.3 square miles (2,752 acres) and is on the Maynard, Massachusetts 7.5-minute USGS quadrangle map. Hudson Road divides the installation into two unequal sections: the larger, northern section (approximately 2,370 acres), and the smaller, southern section (approximately 380 acres). In the late 1970s, the Army identified all of the southern section, except the CFHA, for potential return to the public through excessing. Excessing activities are presently on hold for most of the southern section pending the outcome of facility-wide investigation activities. Any previously excessed areas found to be contaminated will be included in the evaluation and cleanup process.

Current activities in the southern part of the Annex include continuing use of the CFHA as a military family housing area and testing of cloth durability, which is performed in a reserved area at Site P48. Activities in the northern part include use of several individual housing units, a United States Air Force (USAF) radar installation, a drop zone for aerial testing done with remote-controlled aircraft, the Federal Emergency Management Agency (FEMA) regional operations center, the 50 bunkers used for storage by the Army and various leaseholders, and a guardhouse at the main gate. Periodic training exercises are conducted at the site by State Police and National Guard units. The Massachusetts Air National Guard is currently planning to build a communications electronics training complex along the southern boundary of the northern part of the Annex. The installation is also available to a number of permitted recreational users for fishing and other recreational activities. Also, trespassers frequent the Annex because it is easily accessible.

The Annex lies near the western boundary of the Seaboard Lowland Section of the New England-Maritime Physiographic Province. Broad, flat plains with elevations between 190 and 220 feet above mean sea level (AMSL) dominate the land surface at the Annex. Hills are scattered throughout, most of them lying in an arc along the northern boundary and concentrated in the central section of the northern part of the Annex and reaching an elevation of 321 feet AMSL. The lowest level of the installation is 170 feet AMSL along Marlboro

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Brook, near Site P37. A previous investigation classified the topographic features as follows: 81 percent lowlands, 16 percent hills, and 3 percent water bodies (USATHAMA 1980). Unconsolidated deposits of glacial origin cover nearly the entire site. Bedrock outcrops are irregularly distributed, and, in places, bedrock is deeply buried.

2.2.2 Climate and Air Quality

Meteorological data indicate moderately cold, moist winters and warm, moist summers, with an annual mean precipitation level of 121 centimeters (44 inches) per year. Winter precipitation is usually in the form of snow and occasional ice storms. July is recorded as the warmest month, with a mean temperature of 22.2 degrees Celsius (72 degrees Fahrenheit). Temperatures at or above 27 degrees Celsius (81 degrees Fahrenheit) generally occur during the months of June through August with the possibility of temperatures dropping below freezing during the months of December through March. Hurricane-influenced weather patterns can occur during the late summer to early fall months.

Precipitation is usually distributed evenly throughout the year. The driest months are July and October, with an average mean precipitation of 8.5 centimeters (3.3 inches), and the wettest months are March and November, with an average mean precipitation of 12 centimeters (4.7 inches). Summer precipitation is usually confined to short-duration, highintensity thunderstorms (frontal and convection). Winds are light to moderate throughout the year.

The air quality status at Sudbury is regulated by Federal, State, and local environmental laws. The Sudbury Annex is in the Metropolitan Boston Interstate Air Quality Control Region (AQCR 119). The towns of Maynard, Hudson, Marlboro, Stow, and Sudbury are designated as Unclassifiable/Attainment for carbon monoxide. The entire Commonwealth of Massachusetts is designated as a serious non-attainment area for ozone. The region is, however, in attainment for the rest of the criteria pollutants.

The Clean Air Act (CAA) (42 U.S.C. 7401, et seq.) has been enacted by the Federal government to preserve the quality of ambient air. The National Ambient Air Quality Standards (NAAQS) are presented in 40 CFR 50. Management practices, such as waste dumping and open-burning, are regulated by Federal, State, and local environmental laws. State and local toxic air pollutant regulations provide stringent exposure or source emission control requirements for remedial activities or for evaluating site contamination. These regulations will be considered when site investigation results are evaluated. It is noteworthy, at this juncture, that the Commonwealth of Massachusetts has accepted National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations for asbestos, beryllium, and vinyl chloride. In addition, the State has set "acceptable ambient levels" (AALs) for 112 toxic air pollutants. New, modified, or "problem" sources of toxic air pollutants are required to use either best available control technology or lowest achievable emissions reductions to ensure attainment of AALs. The entire Commonwealth is in the Northeast Transport Region as created under the 1990 CAA Amendments, and is therefore subject to more stringent ozone control, including the emissions of volatile organic compounds (VOCs). The Massachusetts Air Pollution Control Regulations are presented in 310 CMR 7.00. The State Ambient Air

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Quality Standards are presented in Massachusetts Department of Environmental Protection (MDEP) regulations (310 CMR 6.00).

2.2.3 Geology

In the following section on geology, glacial deposits and bedrock units are discussed.

2.2.3.1 Glacial Deposits

Wisconsin-stage continental glaciation has had the greatest impact on the topography across the Annex and the New England states in general. Figure 2-1, Surface Geology Map (Hansen 1956), shows eight surficial sediment deposits at the Annex, six of which are associated with glacial processes: kame terraces, kames, kame fields, outwash plains, ground moraines, and drumlins. The other two deposit types are alluvium (reworked outwash sand and gravel) and swamp and lake deposits (gray organic silt and peat). Glacial till, an ice-laid deposit formed during glacial advances, is a compact, unsorted mixture of clay, silt, sand, gravel, and boulders. Generally, the hilly areas of the Annex are composed of till and the broad flat areas are composed of glacial outwash.

Glacial till at the Annex may reach thicknesses of up to 40 feet in ground moraine areas and up to 120 feet in drumlins. In some elevated locations, bedrock is exposed. Over much of the Annex, the till is covered by sand and gravel known as kame and outwash.

Kames are irregular mounds of poorly sorted sand and gravel; kame fields consist of closely spaced mounds. Kame terraces were formed by glacial meltwater streams depositing their load between stagnant ice sheets. Terrace deposits also contain sand and gravel, but are commonly well stratified. Over most of the Annex, till has been overlain by outwash plains. Outwash plains were deposited by meltwater during glacial retreat and consist of sand, silt, and gravel. A one-million-year-old, preglacial river valley, filled with outwash, lies under Boons Pond, White Pond, and the northern part of the detached portion of the Annex (Perlmutter 1962). The top of bedrock is below 100 feet AMSL along its center line, with thicknesses of outwash reaching over 100 feet in places.

2.2.3.2 Bedrock Units

The Annex is underlain by igneous and metamorphic rocks of the Precambrian and Paleozoic Era. As shown on Figure 2-2 (Hansen 1956), six formations underlie the area as part of a tightly folded, northeast-plunging, asymmetrical anticline with a northeasternsouthwest strike. The Marlboro Formation, a fine-grained amphibolitic schist (Precambrian) is exposed on the Annex in a band extending from Vose Hill to White Pond. Two formations cross the southeast corner of the Annex: the Salem Gabbrodiorite, and a quartz diorite facies of the Dedham Granodiorite. Both formations are presumed to be of Devonian age. The Nashoba Formation (Carboniferous), a light gray, biotite gneiss, runs along the northern boundary of the site and underlies the extreme northwest corner of the Annex. Central and

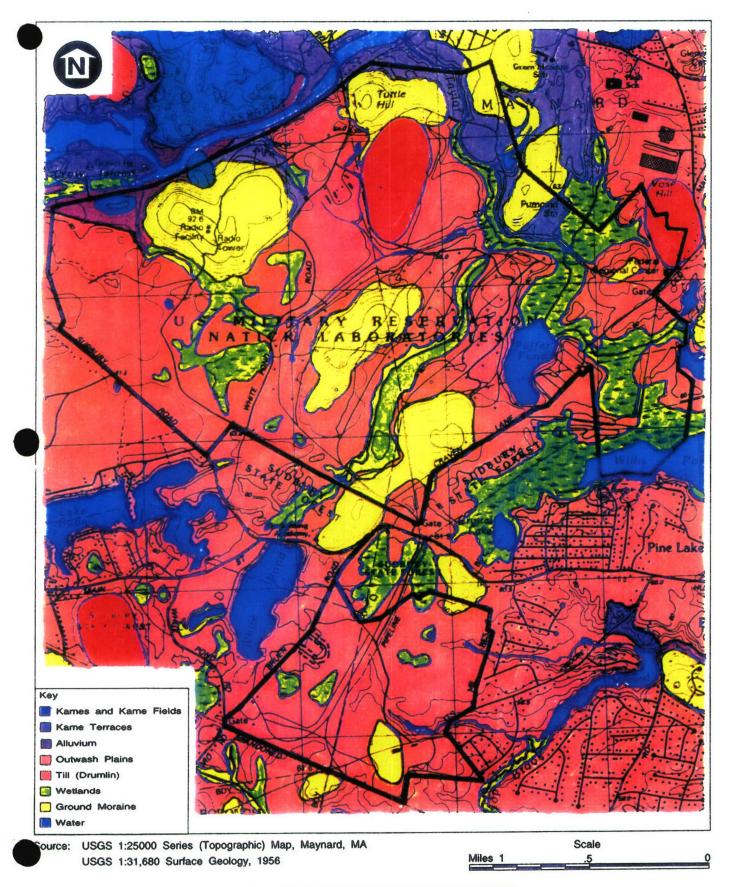
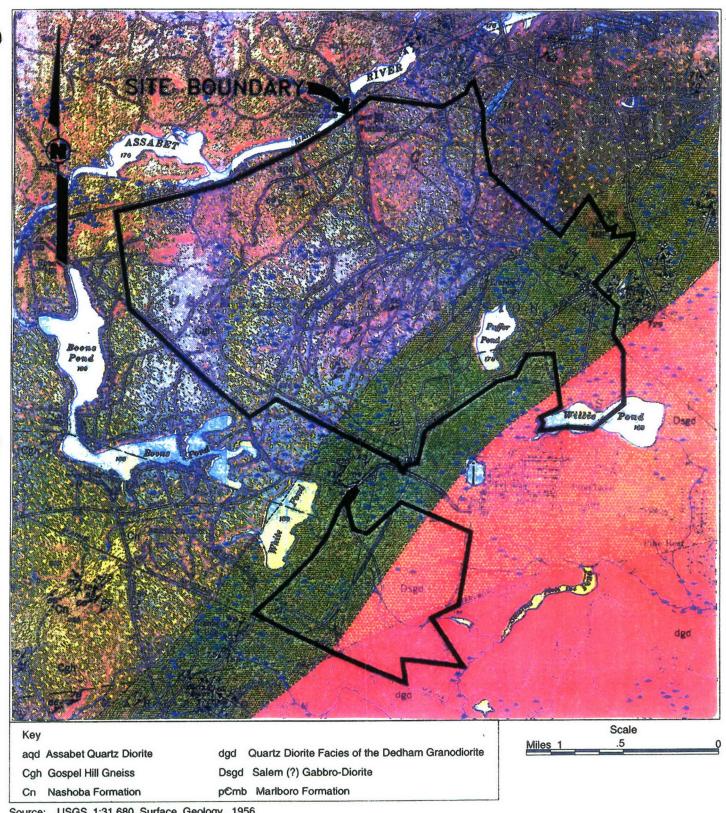


Figure 2-1 SURFACE GEOLOGY AT THE ANNEX



Source: USGS 1:31,680 Surface Geology, 1956 OHM Corporation, 1991

Figure 2-2 BEDROCK GEOLOGY AT THE ANNEX

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northern portions of the Annex are underlain by the Gospel Hill Gneiss (Carboniferous). The Gospel Hill is a medium-to-coarse-textured granite gneiss and is probably a granitized product of the Nashoba and Marlboro Formations. Small bodies of the Assabet Quartz Diorite (Late Paleozoic) crop out in northern portions of the Annex. Past glaciation of the tightly folded bedrock units in the area has produced an irregular bedrock surface.

2.2.4 Soils

Generalized stratigraphic units prevalent across the Annex are soil, outwash, till, and bedrock. Weathering of the glacial deposits and the bedrock has produced the existing soil, but in certain areas, erosion may have removed this soil. Surface soils developed on the kame landforms, the outwash plain, and the alluvium are sandy loam with lenses of gravel. Soils in the lowland swamps and bogs are composed of muck and peat. Soils developed on ground moraines and drumlins are stony loam (U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) 1989).

Soils within the Annex typical of Middlesex County are described below. These soils can be encountered up to 60 inches below ground surface (BGS), and consist of the Paxton, the Merrimac, and the Swansea.

The Paxton is developed within the till deposits and is a well-drained loam. This soil has a 3- to 12-percent clay content, and a permeability of from 0.6 to 2 inches per hour $(4 \times 10^{-4} \text{ to } 1.4 \times 10^{-3} \text{ centimeters per second (cm/sec)})$ at up to 26 inches in depth. Below this depth, compacted tills are encountered with permeability of less than 0.2 inches per hour $(4.4 \times 10^{-4} \text{ cm/sec})$. Organic content ranges from 2 to 5 percent.

The Merrimac soils associated with the outwash deposits are very well-drained and sandy. Clay content ranges from 3 to 7 percent in the first 15 inches, but is less than 4 percent from 15 to 60 inches. Permeability ranges from 2 to 6 inches per hour (1.4×10^{-3}) to 4×10^{-3} cm/sec) from 0 to 22 inches of soil, and up to 20 inches per hour (1.4×10^{-2}) cm/sec) from 22 to 60 inches of soil. Organic content ranges from 1 to 5 percent in the first 15 inches of soil.

The Swansea muck soil is a very poorly drained soil developed in organic deposits of the wetland swamps, bogs, and marshes associated with the low-lying areas scattered throughout the Annex. Clay is found only in the bottom layers (26 to 60 inches) and the clay content can range between 1 and 5 percent. Permeability of this highly organic material runs between 0.6 and 6 inches per hour $(4 \times 10^{-4} \text{ to } 4 \times 10^{-3} \text{ cm/sec})$ to a depth of 26 inches, and greater than 20 inches per hour (1.4 x 10⁻² cm/sec) from 26 to 60 inches of soil, which is below most of the organic muck and peat. Organic content is high (greater than 50 percent) within the first 9 inches of soil (USDA SCS 1989; USDA SCS 1986).

2.2.5 Hydrogeology

The water table at the Annex is generally shallow, as indicated by the numerous wetland areas. Groundwater flow occurs mostly through the outwash plain underlying the

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lowlands. Most of the hills comprising the northwestern third of the Annex, such as Tuttle Hill, are composed of relatively impermeable till or bedrock. These deposits are hydraulically continuous with the outwash, but groundwater moves slowly between these layers and the outwash deposits. The lateral distance of groundwater flow in the glacial aquifers is controlled by changes in glacial and surface geology (i.e., extent of the outwash sand area, impermeable boundary conditions, bedrock outcrops), and groundwater discharges to surface water bodies, such as at streams, rivers, ponds, and wetlands. Transmissivity calculated from investigations conducted in areas of till indicates low yields to wells, less than 10 gallons per minute (gpm), and hence, low hydraulic conductivity (Dufresne-Henry, Inc. 1982).

E & E found that hydraulic conductivities in shallow monitoring wells up to 20 feet deep ranged from 2.25×10^{-4} feet per minute to 3.27×10^{-2} feet per minute with an average hydraulic conductivity of 6.48×10^{-3} feet per minute, which is in the range of that expected for fine or silty sands. Hydraulic conductivities in the two deeper wells, OHM-P40-29 and E3-A05-M01, drilled into the finer outwash at 83.5 and 50 feet, respectively, averaged 6.17×10^{-4} feet per minute.

Conductivity in the deeper well at Site P58, E3-P58-M01, drilled to fine sand at 49 feet, was 2.01×10^{-2} feet per minute and was clearly not located in the less conductive, silty, lake sediments of the typical, low levels of the outwash. This well was possibly in or on the edge of the buried valley of the preglacial Assabet River.

Water supply wells, in the most favorable areas, have yields of up to 400 gpm (FEMA Well) at Puffer Pond and up to 600 gpm at water supply well S115 in Watershed 2, south of Hudson Road. Yields obtained from exploration wells installed during water supply investigations in the elevated hilly areas have produced only negligible quantities of water during standard aquifer pump tests (Dufresne-Henry 1982).

Depth to the groundwater table is generally less than 15 feet, except under hills. Groundwater flow directions are complex, but readily deduced from local topography, since flow is generally from the hills to the swamps, and groundwater divides apparently coincide with topographic divides. Exceptions may occur where buried till or bedrock ridges do not coincide with surface water divides, yet create groundwater divides within the glacial outwash. An example of this occurs under Sites P11 and P13 in Watershed 1B.

A USGS Water Supply Paper (Perlmutter 1962) located and described an important potential water-supply aquifer in outwash, filling in a buried preglacial valley of the former Assabet River. This runs under the west end of Boons Pond, the south end of White Pond in Watershed 5, and turns northeast across Watershed 2, to probably pass under the wetlands adjoining Crystal Lake and Willis Pond in Watershed 6.

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2.2.6 Surface Water and Drainage

A recent survey (Butler 1992) concluded that approximately 25 percent of the Annex area consists of wetlands, and approximately one-third of the Annex is lowland (see Figure 2-3).

The wetlands on and around the Annex are the origin of the streams that traverse and discharge from the area. The four most important wetlands noted are as follows:

- A complex of wetlands associated with Taylor Brook (formerly Puffer Brook) that begins off the Annex to the east above Cutting Pond and Vose Ponds, and continues along the course of Taylor Brook through Puffer Pond to the Assabet River (Watersheds 1A and 1B).
- A group of wetlands south and southeast of the USAF Weather Science Radar Laboratory. This group is the source of surface water flows to Honey Brook (Watershed 1B) and to two unnamed streams, which flow to Watershed 4 to the northwest and to Boons Pond in Watershed 5.
- A large, linear wetland lying between two main groups of bunkers and between Puffer Pond to the east and Honey Brook to the west. This wetland drains north to Taylor Brook and is therefore in Watershed 1A.
- The wetlands south of the main gate, which connect to the Willis Pond wetlands north of Hudson Road and receive drainage from both the detached southern portion of the Annex and the southeast side of the larger northern portion. This entire area is designated as Watershed 6.

Most of the northern portion of the Annex drains northward via Taylor Brook and its tributaries, which flow into the Assabet River (Figure 2-4). Honey Brook, which drains into Taylor Brook, originates in the western section of the Annex and flows just northwest of and along the bunkers. Two small streams also flow from the north portion of the Annex directly into the Assabet.

The southwestern and western sides of the Annex drain primarily into either White Pond or Boons Pond, which discharge to the Assabet River. White Pond has no outlet, but the evidence is that its use as a source of water supply serving the Town of Maynard has resulted in a net in-flow to the pond from the surrounding area. The remainder of the Annex, including nearly all of the detached portion south of Hudson Road, drains into Hop Brook or its tributaries. These include Run Brook, receiving flow from Crystal Lake and Willis Pond, and Marlboro Brook, which originates on the Annex. Hop Brook discharges to the Sudbury River, which joins the Assabet River northeast of the Annex to form the Concord River.

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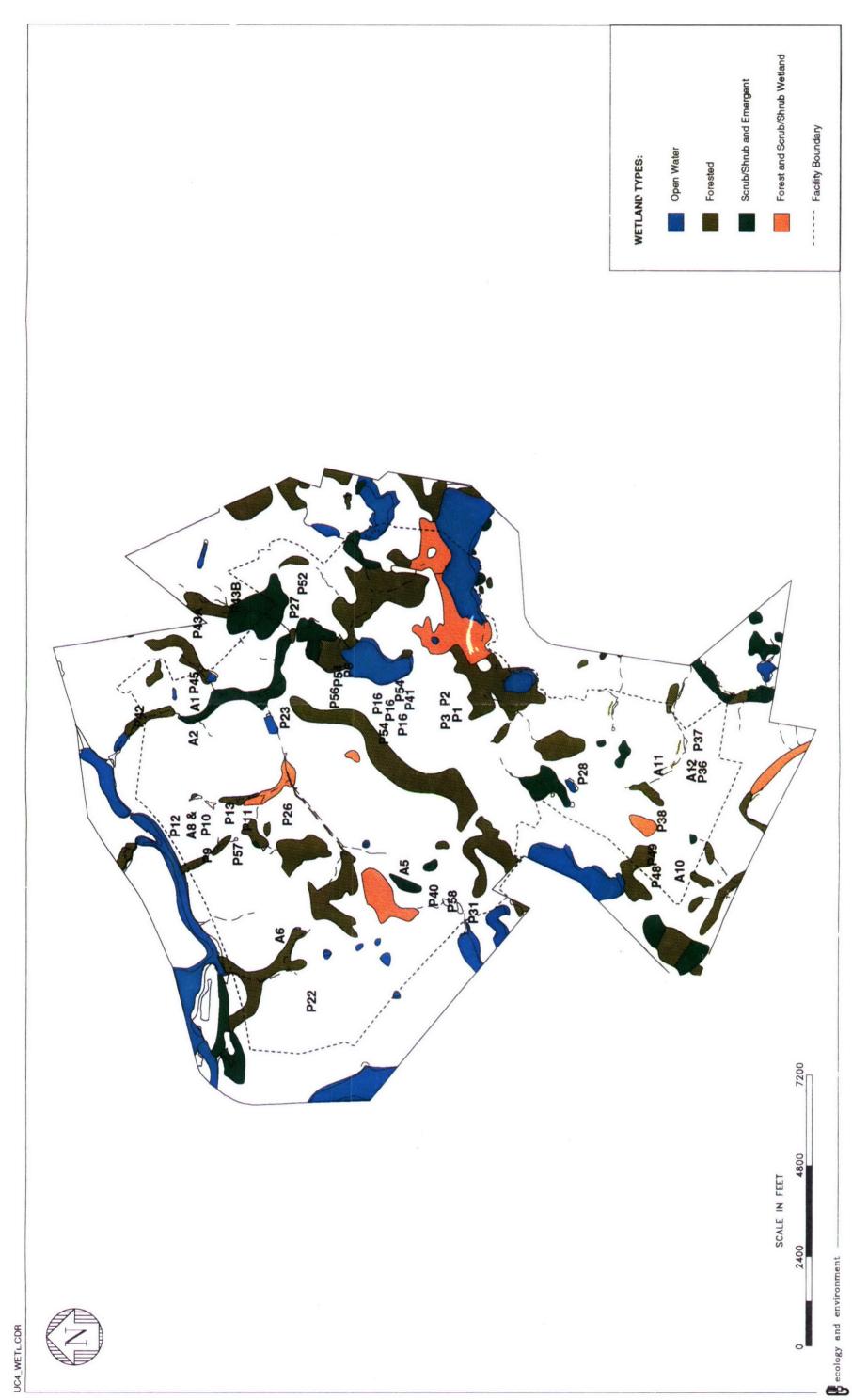
The Assabet River, located in the Concord River Basin and in the vicinity of the Annex, has a water quality classification of Class B, designated by the Massachusetts Department of Environmental Quality and Engineering (now MDEP) for use, protection, and propagation of fish; other aquatic life and wildlife; and for primary and secondary contact recreation (MADEQE 1989). Wherever so designated, the MDEP states that Class B waters "shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses. These waters shall be consistently good aesthetic quality." Several wastewater treatment plants in the towns of Westborough, Shrewsbury, Marlborough, and Hudson discharge into the Assabet River upstream of the Annex.

On-site conditions are conducive to good infiltration/percolation rather than runoff. The little runoff that does occur from the small hills is presumed to infiltrate into the welldrained outwash soils or to discharge directly to wetlands and streams. It may be assumed that lakes and swampy areas indicate areas where the top of the saturated zone (water table) is above the surface, either permanently or seasonally. Flow direction from these relatively flat wetland areas is sometimes difficult to determine and may in fact change direction during local storm events. No detailed studies were performed on surface flow during either of the previous remedial investigations conducted for sites at the Annex (Dames and Moore 1986b; OHM 1994).

2.2.7 Demography and Land Use

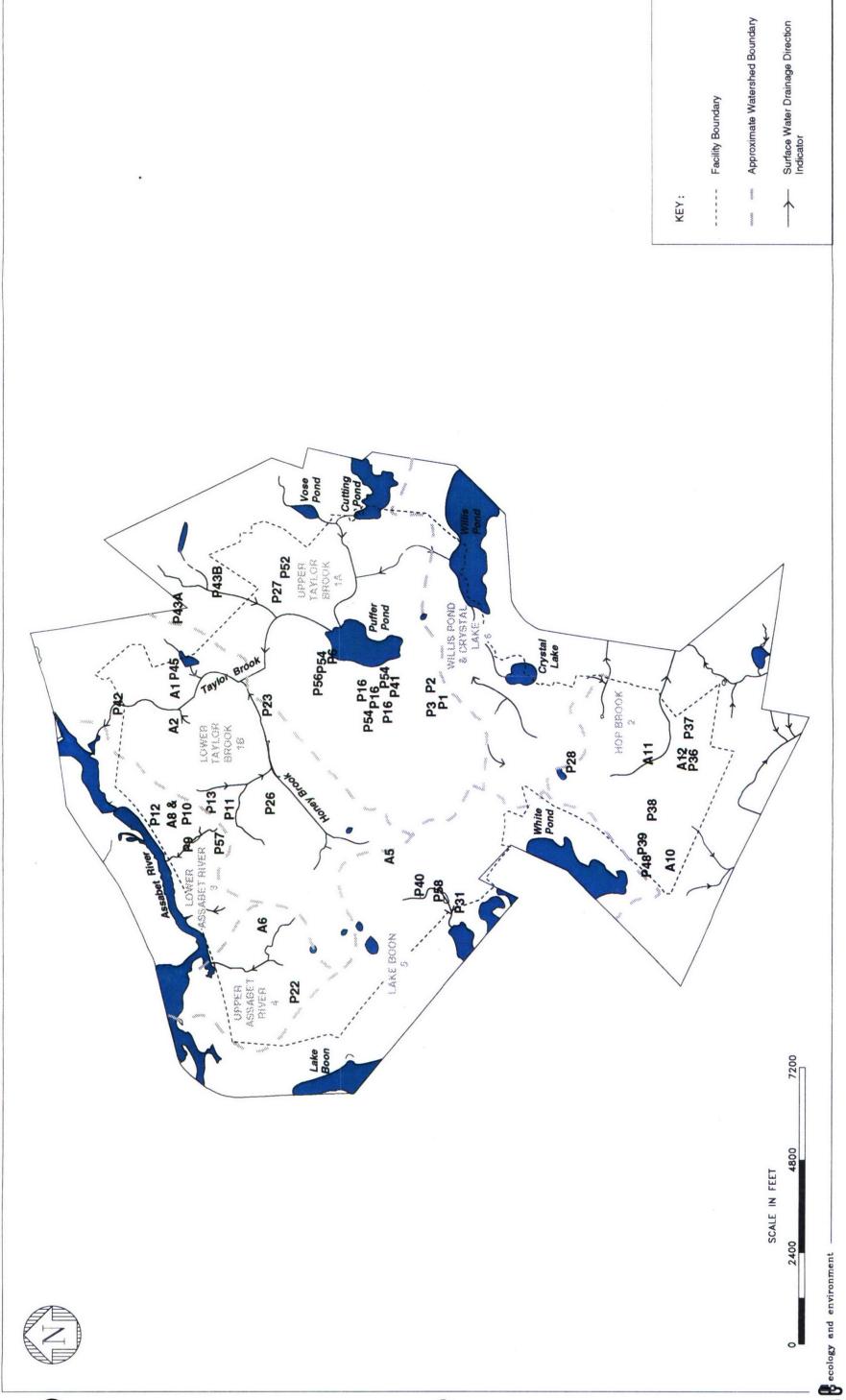
The Annex is located on 2,752 acres of land, where 2,575 acres are managed as woodlands. As of August 1993, the United States Army Natick Research and Development Laboratory Family Housing Office reported 35 families residing in the CFHA, the only residential area at the Annex. However, none of the residents work at the Annex (United States Department of Health and Human Services (USDOHHS) 1993).

Four towns and the community of Lake Boon surround the Annex. Hudson is the largest of the towns with a population in the 1990 Census of 16,408. The town lies four miles southwest of the Annex, and has approximately 84 percent of the population between the ages of five and sixty-four. Sudbury is the next largest town with a 1990 population of 14,358. The town of Sudbury lies 2.8 miles southeast of the Annex, and has 90 percent of the population between the ages of five and sixty-four. In 1990, Maynard had a population of 5,328, where 82 percent of the population was between the ages of five and sixty-four. This town lies two miles northeast of the Annex. The town of Stow is located northwest of the Annex and had a 1990 population of 5,328. Approximately 87 percent of the residents are between the ages of five and sixty-four. The community of Lake Boon is also located to the west of the Annex. There are 543 housing units with 1,402 residents. Approximately 27 percent of the residents are below the age of 18, 69 percent are between the ages of 18 and 65, and 4 percent are over the age of 65 (USDOHHS 1993).



SOURCE: Compiled by Ecology and Environment, Inc. from National Wetland Inve.:tory Map 1977.

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SOURCE: Compiled by Ecology and Environment, Inc. 1994.

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The Annex has been closed to Army reserve and active duty training activities since October 1992. However, several organizations have been granted permission to conduct occasional training. The Army uses 780 acres as a field evaluation test course. The USAF leases 500 acres for radar instrumentation research, 80 acres for an antennae farm, and has some full-time staff at the Annex. FEMA leases approximately 262 acres near the eastern boundary. The southern portion of the Annex, the CFHA, occupies 18 acres and includes a small recreational area for children. In the northern portion of the Annex, about 850 acres contain concrete, earth-covered bunkers which had been used for ordnance storage in the past. The Army currently leases some of the bunkers to State and Federal agencies for storage of equipment, supplies, chemicals, and herbicides. The Tennessee Gas Company has an agreement with Fort Devens for a right-of-way easement for pipeline installation and maintenance (USDOHHS 1993).

The Army is obligated by the National Historic Preservation Act of 1966 to identify cultural resources at the Annex, and to ensure conservation of these resources through the appropriate programs. In 1984, Public Archaeology Laboratory, Inc. conducted a survey which identified 25 prehistoric cultural resources. Three areas are being considered for registration with the National Register of Historic Places (USDOHHS 1993).

The area around the Annex is mainly residential interspersed with agricultural areas and light industry. Green Meadow Elementary School and Maynard Public High School are adjacent to property excessed by the Annex in 1977. Fairbank Elementary School in Sudbury is within one mile east of the Annex. Boons Pond (also known as Lake Boon) and White Pond, both west of the Annex and between the northern and southern portions, are used for fishing. The Assabet River, located north of the Annex, flows eastward and is also used for fishing. Some of the excessed Army property that is now the Marlboro Sudbury State Forest is used for dirt biking (USDOHHS 1993).

2.2.8 Groundwater Use and Quality

Both surface water and groundwater are used for potable water within a three mile radius of the Annex. Depending on location, drinking water is supplied by either domestic (private) wells, municipal (public or town) wells, surface water, bottled water, or by a combination of the four (USDOHHS 1993).

The northern portion of the Annex has five on-site water supply wells. However, none are currently used for drinking water. The guest house well was previously used as a potable water supply for the three guest units, which are no longer occupied. Based on sampling depth, the well appears to be completed in the surficial aquifer. The USAF radar facility well is 350 feet deep and was used for potable purposes until March 1991. At that time, the selenium concentration in the well water (30 parts per billion (ppb)) was above the Massachusetts Department of Environmental Protection standard of 10 ppb. The USAF now uses bottled water. The guardhouse well at the Main Gate is used for washing vehicles, sanitary purposes, and watering the lawn. Water from the Civil Defense Well, located on the eastern bank of Puffer Pond, is used only to cool generators at FEMA. According to the FEMA facilities manager, water used for cooling generators and sewage is either from

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Maynard's municipal system or from the Civil Defense Well. Because of preferable taste, bottled spring water is used as a drinking water source. The supply well for the Deputy Commander's house is abandoned and the house is not occupied (USDOHHS 1993).

On the southern portion of the site, drinking water for the CFHA has been supplied by the town of Hudson since summer 1992. The 35 houses had previously received water from the Maynard distribution system (USDOHHS 1993).

Three of the nearby towns use groundwater from the surficial aquifer as part or all of their municipal (public or town) water supply. Sudbury has eight municipal wells, with a depth of about 60 feet, that service approximately 14,000 residents. Hudson has four municipal wells and one surface water source (Gates Pond) in Berlin, which is west of Hudson, that services approximately 4,200 residents. Maynard is currently drawing water from two municipal wells and one surface water source, White Pond, which is south of Hudson Road between the northern and southern portions of the Annex. The Maynard public water system services approximately 12,000 residents. Surface water sources are blended with groundwater sources in Hudson and Maynard before distribution. About 40,000 people use public or private drinking water supplies within three miles of the Annex (USDOHHS 1993).

Although the majority of the Hudson, Maynard, and Sudbury residences are connected to municipal water systems, private wells are used in some areas. The town of Hudson has about 270 private wells in addition to the public water system. Some Hudson residences on Lake Boon, Concord Road, and Parmenter Street have private wells. In Maynard, there are homes with wells on Riverside Park, a private road near the Assabet River Bridge on White Pond Road (Old Lancaster Road). There is also a home on Old Puffer Road and another home in the same vicinity on Maynard Road (Route 27) with private wells. In Sudbury, there are a few homes with private wells around Willis Pond and along Maynard Road near Willis Hill. The town of Stow is served by private wells. The depths of the private wells are unknown, but most are probably completed in the surficial aquifer (USDOHHS 1993).

None of the above wells in use or potentially in use are impacted by any identified site or monitored area on the Annex. All sites so far identified at the Annex have groundwater flows that discharge to surface water without flowing through an area used as a source of drinking water. The nearest any site comes to showing potential impact on existing wells is at Site P31 along Hudson Road. A well there shows filtered samples with arsenic exceeding the MCL. The groundwater in this area discharges to Boon's Pond but passes within a few hundred feet of existing domestic wells.

The USGS identified an important potential water-supply aquifer in outwash, filling in a buried preglacial valley of the former Assabet River (Perlmutter 1962). This aquifer extends under the detached portion of the Annex south of Hudson Road, and has not been shown to be affected by any of the sites investigated. Potential impacts from Sites P28 and P38 have not been investigated by the installation of monitoring wells. The former backup well for the Town of Maynard (S115) located in this aquifer was tested by the USGS

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(Perlmutter 1962), and "the concentrations of iron and manganese together (1.05 ppm) . . . is more than three times as high as the generally accepted standard of 0.3 ppm." This exceedance is almost certainly natural and has nothing to do with any of the sites on the Annex.

2.2.9 Facility Ecology

This section contains a brief introduction to the regional ecology of the Annex, a partial description of past and present land use, and an overview of ecosystems and habitat types encountered at the Annex. Volumes II and III contain more detailed, site ecological characterizations, which identify habitat types, sensitive environments downgradient of the various sites, use by wildlife, and species-of-concern associated with each site.

Because of the long growing season, abundant rainfall, and fertile soils, inland areas of the Commonwealth of Massachusetts support a variety of productive ecosystems. The regional vegetation consists primarily of mixed coniferous and deciduous forest. According to Eyre (1980), the Annex is within the Eastern White Pine and Scarlet Oak forest cover types.

The varied topography, the diversity of soil types, and the relatively complex drainage of the Annex, in combination with human interference, have resulted in a mosaic of forests, grasslands, wetlands and open water areas. The forest vegetation is dominated by oak and white pine in drier areas, and red maple and ash in wetter areas. Mixed oak forests cover most of the southern portion of the Annex, and a mixture of white pine and oak is the predominant forest type in the northern portion (Figure 2–5). Open areas vegetated with grasses, forbs, and cherry bushes are scarce, mostly occurring in the southern (drier) part of the Annex and around the abandoned buildings found throughout the Annex. Grass-leaved Ladies' Tress was identified in an unmowed field in the northwest part of the site (Aneptek 1991).

Wetlands cover approximately 25 percent of the Annex area (United States Department of the Interior (USDOI) 1977; Butler 1992) and are a combination of forested, scrub/shrub, and emergent wetlands, occurring primarily along streams, rivers, and open bodies of water. The most common wetland type at the Annex is the forested wetland (Figure 2-5). No state-listed, rare wetlands have been identified within a 1.5 mile radius of the Annex (Massachusetts Natural Heritage and Endangered Species Program (MNHESP) 1992).

Open bodies of water at the Annex include lakes such as Puffer Pond, Crystal Lake, and Willis Pond; several small vernal pools such as Gas Shack Pool, South Sphagnum Pool, and North Gate Pool (Butler 1992); oxbow ponds found along the Assabet River; and the Assabet river itself.

The presence of old stone foundations, small fields bounded by stone walls, and numerous overgrown roads indicate that prior to the Army's acquisition of the Annex, the land was predominantly used for agriculture. Since acquisition by the Army, the Annex has been allowed to revegetate naturally to its present, largely forested state. Occasional logging practices and military activities do not appear to have had any impact on the forested areas.

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The largest, recent timber harvest occurred in 1983, a salvage operation after a hurricane. There have been smaller harvests since that time; to date, approximately one million board feet of lumber has been harvested.

The following subsections briefly describe the prevalent ecosystems at the Annex. Tables 2-1 through 2-4 provide a list of birds, mammals, reptiles and amphibians, as well as plants likely to occur on the Annex. Table 2-5 identifies Federal or State-listed species that have been observed at the Annex.

2.2.9.1 Aquatic Ecosystems

The aquatic ecosystem at the Annex consists of a complex network of intermittent and perennial streams, rivers, and ponds. In general, aquatic habitats are valuable to wildlife because they support a diverse, benthic macroinvertebrate community as well as phytoplankton and zooplankton, which constitute the base of the food chain and in turn provide food sources for all other wildlife.

The largest body of standing water within the facility boundaries is Puffer Pond. This habitat supports many aquatic insects, crustaceans, mollusks, fish, amphibians, reptiles, waterfowl, and piscivorous birds. Several species of fish, including chain pickerel, largemouth bass, bluegill, yellow perch, and brown bullhead, have been identified in Puffer Pond (OHM 1994). During a field survey conducted by E & E in November 1993, two Massachusetts State watch-list species, an osprey (Pandion haliaeetus) and a great blue heron (Ardea herodias), were observed feeding in Puffer Pond. The bald eagle is also likely to frequent the pond and dive for fish in the deeper portions. Finally, snapping turtles, painted turtles, and northern water snakes are also known to occur in this pond (OHM 1994).

Streams and rivers are also of great value to wildlife because they provide easy access to drinking water, protected sites for dens and nests, sunny areas for berry-producing bushes to grow, and safe travel corridors for many species. Fish, crustaceans, insects, plants, reptiles, amphibians, birds, and many upland species can be observed in this habitat type. The largest perennial stream at the Annex, Taylor Brook, originates in Puffer Pond and flows north towards the Assabet River. The major tributary to Taylor Brook is the north-flowing Honey Brook. These streams are also known to support rich, benthic macroinvertebrate communities which include mayflies, stoneflies, caddis flies, blood worms, and side swimmers (OHM 1994). Finally, black crappies, bluegills, brown bullheads, eastern brook trout, redbreast sunfish, and white perch are some of the fish known to occur in the Assabet river, which is located immediately adjacent to the northwestern boundary of the Annex (Maietta 1986).

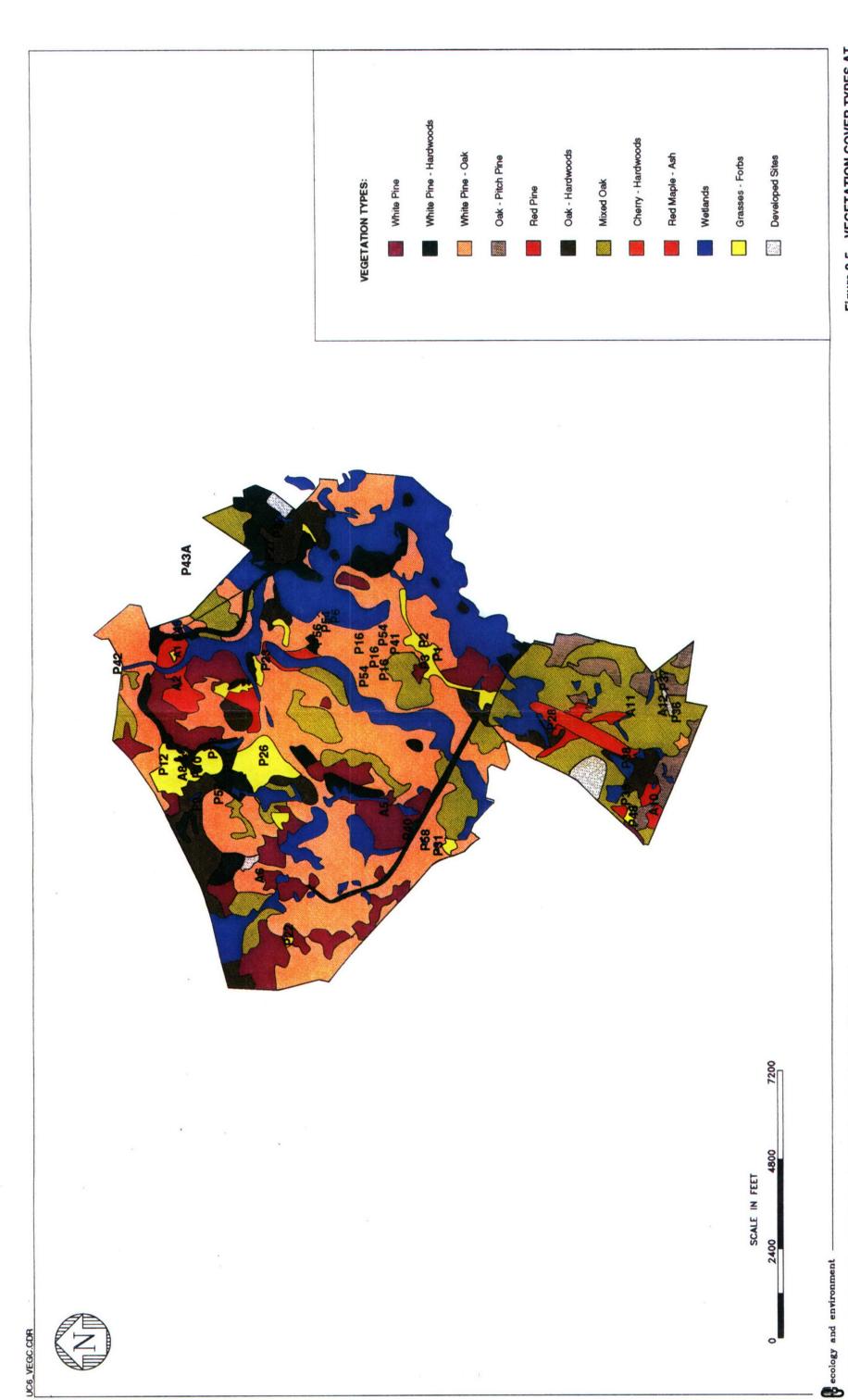


Figure 2-5 VEGETATION COVER TYPES AT THE SUDBURY ANNEX

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SOURCE: Forest and Land Cover Map, Leupold Forestry Service 1983, compiled by Ecology and Environment, Inc.

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Table 2-1 BIRDS AT THE SUDBURY ANNEX, MASSACHUSETTS		
Common Name Scientific Name		
Alder flycatcher	Empidonax alnorum	
American black duck	Anas rubripes	
American crowb	Corvus brachyrhynchos	
American goldfinch ^b	Carduelis tristis	
American kestrel ^b	Falco sparverius	
American redstart	Setophaga ruticilla	
American robin ^b	Turdus migratorius	
American tree sparrow	Spizella arborea	
American woodcock	Scolopax minor	
Bald eagle	Haliaeetus leucocephalus	
Barn swallow	Hirundo rustica	
Barred owl	Strix varia	
Belted kingfisher	Ceryle alcyon	
Black and white warbler ^b	Mniotilta varia	
Black-billed cuckoo	Coccyzus erythrophthalmus	
Black-capped chickadee ^b	Parus atricapillus	
Black-crowned night-heron	Nycticorax nycticorax	
Black-throated blue warbler	Dendroica caerulescens	
Black-throated green warbler	Dendroica virens	
Blue-gray gnatcatcher	Polioptila caerulea	
Blue jay ^b	Cyanocitta cristata	
Bobolink	Dolichonyx oryzivorus	
Broad-winged hawk	Buteo platypterus	
Brown creeper	Certhia americana	
Brown-headed cowbird ^b	Molothrus ater	
Brown thrasher	Toxostoma rufum	
Canada goose	Branta canadensis	
Canada warbler	Wilsonia canadensis	
Cedar waxwing ^b	Bombycilla cedrorum	
Chestnut-sided warbler	Dendroica pensylvanica	
Chimney swift ^b	Chaetura pelagica	
Chipping sparrow	Spizella passerina	
Common grackle	Quiscalus quiscula	
Common yellowthroat ^b	Geothlypis trichas	
Dark-eyed junco	Junco hyemalis	
Downy woodpecker	Picoides pubescens	
Eastern bluebird ^a	Sialia sialis	
Eastern kingbird ^b	Tyrannus tyrannus	

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Table 2-1		
BIRDS AT THE SUDBURY ANNEX, MASSACHUSETTS		
Common Name Scientific Name		
Eastern meadowlark	Sturnella magna	
Eastern phoebe ^b	Sayornis phoebe	
Eastern screech owl	Otus asio	
Eastern wood-pewee	Contopus virens	
European starling ^b	Sturnus vulgaris	
Evening grosbeak	Coccothraustes vespertinus	
Field sparrow ^b	Spizella pusilla	
Golden-crowned kinglet	Regulus satrapa	
Gray catbird ^b	Dumetella carolinensis	
Great blue heron	Ardea herodias	
Great crested flycatcher ^b	Myiarchus crinitus	
Great horned owl	Bubo virginianus	
Green-backed herona	Butorides striatus	
Hairy woodpecker	Picoides villosus	
Herring gull ^b	Larus argentatus	
Horned lark	Eremophial alpestris	
House finch ^b	Carpodacus mexicanus	
House sparrow ^b	Passer domesticus	
House wren	Troglodytes aedon	
Indigo bunting	Passerina cyanea	
Killdeer	Charadrius vociferus	
Least flycatcher	Empidonax minimus	
Mallard	Anas platyrhynchos	
Mourning dove ^b	Zenaida macroura	
Nashville warbler	Vermivora ruficapilla	
Northern cardinal ^b	Cardinalis cardinalis	
Northern flicker ^b	Colaptes auratus	
Northern mockingbird ^b	Mimus polyglottos	
Northern oriole ^b	Icterus galbula	
Northern saw-wet owl	Aegolius acadiars	
Nothern waterthrush	Seiurus noveboracensis	
Osprey	Pandion haliaetus	
Ovenbird ^b	Seiurus aurocapillus	
Pileated woodpecker	Dryocopus pileatus	
Pine siskin	Carduelis pinus	
Pine warbler	Dendroica pinus	
Prairie warbler	Dendroica discolor	
Purple finch ^b	Carpodacus purpureus	

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	Tab	ole 2-1	
BIRDS AT	THE SUDBURY	ANNEX,	MASSACHUSETTS

Common Name	Scientific Name	
Purple martin	Progne subis	
Red-breasted nuthatch	Sitta canadensis	
Red-eyed vireo	Vireo olivaceus	47
Red shouldered hawk	Buteo lineatus	
Red-tailed hawk ^b	Buteo jamaicensis	
Red-winged blackbird ^b	Agelaius phoeniceus	
Ring-billed gull	Larus delawarensis	
Ring-necked pheasant	Phasianus colchicus	
Rock dove ^b	Columba livia	
Rose-breasted grosbeak	Pheucticus ludovicianus	
Rough-legged hawk	Buteo lagopus	
Ruby-throated hummingbird	Archilochus colubris	
Ruffed grouse ^b	Bonasa umbellus	
Rufous-sided townheeb	Pipilo erythrophthalmus	
Savannah sparrow	Passerculus sandwichensis	
Scarlet tanager	Piranga olivacea	
Snow bunting	Plectrophenax nivalis	
Song sparrow ^b	Melospiza melodia	
Sora	Porzana carolina	
Spotted sandpiper	Actitus macularis	
Swamp sparrow	Melospiza georgiana	
Tree swallow	Tachycineta bicolor	
Tufted titmouse	Parus bicolor	
Veery	Catharus fuscescens	
Virginia rail ^a	Rallus limicola	
Warbling vireo	Vireo gilvus	
White-breasted nuthatch	Sitta carolinensis	
White-throated sparrow	Zonotrichia albicollis	
Wild turkey ^b	Meleagris gallopavo	
Willow flycatcher	Empidonax traillii	
Wood duck	Aix sponsa	
Wood thrush	Hylocichla mustelina	
Yellow-billed cuckoo	Coccyzus americanus	
Yellow-throated vireo	Vireo flavifrons	

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Table 2-1		
BIRDS AT THE SUDBURY ANNEX, MASSACHUSETTS		
Common Name Scientific Name		
Yellow-rumped warbler	Dendroica coronata	
Yellow warbler Dendroica petechia		

Species observed during field survey conducted by Brian O. Butler (Fort Devens Sudbury Annex Inventory Summary Report by Butler, B.O., 1992).

Species observed during field surveys conducted 21-23 June 1993.

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

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Table 2-2	
MAMMAL SPECIES AT THE SUDBURY	ANNEX, MASSACHUSETTS

Common Name	Scientific Name	
Beaver	Castor canadensis	
Big brown bat	Eptesicus fuscus	
Bobcat	Lynx rufus	
Deer mouse	Peromyscus maniculatus	
Eastern chipmunk ^a	Tamias striatus	
Eastern cottontail ^a	Sylvilagus floridanus	
Eastern gray squirrel ^a	Sciurus carolinensis	
Eastern mole	Scalopus aquaticus	
Eastern pipistrel	Pipistrellus subflavus	
Fisher	Martes pennanti	
Hairytail mole	Parascalops breweri	
House mouse	Mus musculus	
Keen's myotis	Myotis keenii	
Little brown bat	Myotis lucifugus	
Long-tail weasel	Mustela frenata	
Masked shrew	Sorex cinereus	
Meadow jumping mouse	Zapus hudsonius	
Meadow vole	Microtus pennsylvanicus	
Mink	Mustela vison	
Muskrat	Ondatra zibethica	
Norway rat	Rattus norvegicus	
Pine vole	Pitymys pinetorum	
Raccoon ^a	Procyon lotor	
Red bat	Lasiurus borealis	
Red fox	Vulpes vulpes	
Red squirrel ^a	Tamiasciurus hudsonicus	
Short-tail weasel	Mustela erminea	
Shorttail shrew	Blarina brevicauda	
Silver-haired bat	Lasionycteris noctivagens	
Smokey shrew	Sorex fumeus	
Southern flying squirrel	Glaucomys volens	
Star-nosed mole	Condylura cristata	
Striped skunk	Mephitis mephitis	
Virginia opossum	Didelphis virginiana	
White-footed mouse	Peromyscus leucopus	

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Table 2-2		
MAMMAL SPECIES AT THE SUDBURY ANNEX, MASSACHUSETTS		
Common Name Scientific Name		
White-tail deer ^a	Odocoileus virginianus	
Woodchuck ^a	Marmota monax	

Evidence of these species was observed during the 21-23 June 1993, field survey (i.e., scats, tracks, dens, or individuals).

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

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Table 2-3 AMPHIBIANS AND REPTILES WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
American toad	Bufo americanus
Bullfrog ^a	Rana catesbiana
Common musk turtle	Sternotherus odoratus
Common snapping turtle	Chelydra serpentina
Eastern garter snake ^a	Thamnophis sirtalis
Eastern milk snake	Lampropeltis triangulum
Eastern painted turtle ^a	Chrysemys picta
Eastern ribbon snake	Thamnophis sauritus
Eastern smooth green snake	Opheodrys vernalis
Gray treefrog	Hyla versicolor
Green frog ^a	Rana clamitans
Northern black racer	Coluber constrictor
Northern brown snake	Storeria dekayi
Northern dusky salamander	Desmognathus fuscus
Northern leopard frog	Rana pipiens
Northern redbelly snake	Storeria occipitomaculata
Northern ringneck snake	Diadophis punctatus
Northern two-lined salamander	Eurycea bislineata
Northern water snake	Nerodia sipedon
Pickerel frog	Rana palustris
Red-spotted newt	Notophthalmus viridescens
Redback salamander	Plethodon cinereus
Spotted salamander	Ambystoma maculatum
Spring peeper	Hyla crucifer
Wood frog	Rana sylvatica

a Observed during the 21-23 June 1993 field surveys.

Source: Ecology and Environment, Inc. 1993; DeGraaf and Rudis 1986.

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Table 2-4

COMMON PLANT SPECIES IDENTIFIED^a AT THE SUDBURY ANNEX, MASSACHUSETTS

SUDBURY ANNEX, MASSACHUSETTS		
Common Name	Scientific Name	
Alternate-Leaved Dogwood	Cornus alternifolia	
American Chestnut	Castanea dentata	
Arrow-leaved tearthumb	Polygonum sagittatum	
Big-Toothed Aspen	Populus grandidentata	
Birds-foot Trefoil	Lotus Corniculatus	
Black Cherry	Prunus serotina	
Black Locust	Robinia pseudoacacia	
Blackberry	Rubus allegheniensis	
Boneset	Eupatorium perfoliatum	
Broad-Leaved Cattail	Typha latifolia	
Canada Mayflower	Malanthemum canadense	
Cinnamon Fern	Osmunda cinnamomea	
Common Cinquefoil	Potentilla rects	
Common Greenbriar	Smilax rotundifolia	
Common Milkweed	Asclepias syriaca	
Cottonwood	Populus deltoides	
Cow Vetch	Vicia cracca	
Dwarf Snapdragon	Chaenorrhinum minus	
Eastern White Pine	Pinus strobus	
Field Hawkweed	Hieracium pratense	
Field Sorrel	Rumex acetosella	
Fire Cherry	Prunus pensylanica	
Flowering Dogwood	Cornus florida	
Gray Birch	Betula populifolia	
Green Ash	Fraxinus pennsylvanica	
Ground cedar	Lycopodium tristachym	
Hairy Solomon's Seal	Polygonatum pubescens	
Hop Clover	Trifolium agrarium	
Indian Cucumber	Medeola virginiana	
Indian Paintbrush	Hieracium aurantiacum	
Indian Pipe	Monotropa uniflora	

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Table 2-4

COMMON PLANT SPECIES IDENTIFIED^a AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Jack-in-the-Pulpit	Arisaema atrorubens
Japanese barberry	Berberis thunbergii
Little Bluestem	Schizachyrium scoparium
Lowbush Blueberry	Vaccinium angustifolia
Meadowsweet	Spiraea latifolia
Mountain Laurel	Kalmia latifolia
Multiflora Rose	Rosa multiflora
Northern Arrowwood	Viburnum recognitum
Northern Red Oak	Quercus rubra
Orchard Grass	Dactylis glomerata
Panic Grass	Panicum sp.
Paper Birch	Betula papyrifera
Partridge-Berry	Mitchella repens
Pink Ladyslipper	Cypripedium
Poison Ivy	Toxicodendron radicans
Poverty Grass	Danthonia spicata
Privet	Ligustrum vulgare
Queen Anne's Lace	Daucus carota
Rabbit-foot Clover	Trifolium arvense
Red Cedar	Junipernus virginiana
Red Clover	Trifolium pratense
Red Maple	Acer rubrum
Red Pine	Pinus resinosa
Reed Canary Grass	Thalaris arundinacea
Rice Cutgrass	Leersia oryzoides
Round-Headed Bush Clover	Lespedeza prucumbens
Royal Fern	Osmunda regalis
Rugosa Rose	Rosa ritida
Scarlet Oak	Quercus coccinea
Scotch Pine	Pinus sylvestris
Sensitive Fern	Onclea sensibilis

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Table 2-4

COMMON PLANT SPECIES IDENTIFIED^a AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Shagbark Hickory	Carya ovata
Sheep Laurel	Kalmia angustifolia
Skunk Cabbage	Symplocarpus foetidus
Slender Blue Flag Iris	Iris primatica
Slippery Elm	Ulmus rubra
Small Yellow Pond Lily	Nuphar microphyllum
Smooth Sumac	Rhus Glabra
Speckled Alder	Alnus rugosa
Sphagnum Moss	Sphagnum sp.
Spotted Jewelweed	Impatiens capensis
Starflower	Trientalis borealis
Stiff clubmoss	Lycopodium annotinum
Swamp Candles	Lythrum terrestris
Sweetfern	Comptonia pergrina
Timothy Grass	Phleum pratense
Tree Clubmoss	Lycopodium obscurum
Unidentified Aster	Aster sp.
Unidentified Goldenrod	Solidage sp.
Virginia Creeper	Parthenocissus quinquefolia
White Ash	Fraxinus americana
White Clover	Trifolium repens
White Spruce	Picea glauca
White Sweet Clover	Melilotus alba
Whorled Loosestrife	Lythrum quadrifolia
Wild Grape	Vitis sp.
Wild Sarsaparilla	Aralia nudicaulis
Winterberry	Ilex verticillata
Yarrow	Achillea millefolium

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Table 2-4

COMMON PLANT SPECIES IDENTIFIED^a AT THE SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name		
Yellow Sweet Clover	Melilotus officinalis		
Yellow Wood Sorrel	Oxalis montana		

a Plant species were identified during a field survey conducted 21-23 June 1993.

Source: Ecology and Environment, Inc. 1993.

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		Ta	ble 2	2-5			
SPECIES	OF	CONCERN	AT	THE	SUDBURY	ANNEX	

Common Name	Common Name Scientific Name Status ^a		Reference
Plants			
Blazing Star	Liatris borealis	Watch List (Massachusetts)	Hunt 1992
Few-Seeded Sedge	Carex oligosperma	Threatened (Massachusetts)	Hunt 1992
Grass-leaved Ladies' Tressb	Spiranthes vernalis	Species of Special Concern (Massachusetts)	Aneptek 1991
Lacegrass	Eragrotis capillaries	Watch List (Massachusetts)	Hunt 1992
Midland Sedge	Carex mesochorea	Endangered (Massachusetts)	Hunt 1992
Northern Starwort	Stellaria calicantha	Watch List (Massachusetts)	Hunt 1992
Red Pine	Pinus resinosa	Watch List (Massachusetts)	Hunt 1992
Small Beggar Ticks	Bidens discoidea	Watch List (Massachusetts)	Hunt 1992
Wood Witchgrass	Panicum philadelphicum	Species of Special Concern (Massachusetts)	Hunt 1992
Birds			
Bald Eagle	Haliaeetus leucocephalus	Endangered (Federal List)	Aneptek 1991, OHM July 199
Eastern Bluebird	Sialia sialis	Watch List (Massachusetts)	Aneptek 1991
Great Blue Heron	Ardea herodias	Watch List (Massachusetts)	E & E November 199
Osprey	Pandion haliaeetus	Watch List (Massachusetts)	E & E November 199
Purple Martin	Progne subis	Watch List (Massachusetts)	Aneptek 1991
Red-Shouldered Hawk	Buteo lineatus	Watch List (Massachusetts)	OHM 1994
Reptiles and Amphibians			
Blanding's Turtle	Emydoidea blandingii	Threatened (Massachusetts)	OHM 1994
Blue Spotted Salamander	Ambystoma laterale	Species of Special Concern (Massachusetts)	Butler 1992
Spotted Turtle	Clemmys guttata	Species of Special Concern (Massachusetts)	Butler 1992
Spotted Salamander	Ambystoma maculatum	Watch List (Massachusetts)	Butler 1992

The following definitions of endangered, threatened, and special concern species were obtained from the Natural Heritage and Endangered Species Program, Boston, Massachusetts.

ENDANGERED: "Any species of plant or animal in danger of extinction throughout all or a significant portion of its range and species of plants or animals in danger of extirpation as documented by biological research and inventory."

THREATENED: "Any species of plant or animal likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and any species declining or rare as determined by biological research and inventory, and likely to become endangered in the foreseeable future."

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SPECIAL CONCERN: "Any species of plant or animal which has been documented by biological research and inventory to have suffered a decline that could threaten the species if allowed to continue unchecked or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become threatened within Massachusetts." (Source: 321 CMR 10.03)

WATCH LIST: Any species of plant or animal which has been documented by biological research and inventory to have suffered a decline or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become a species of special concern within Massachusetts. (Source: Natural Heritage and Endangered Species Program, Boston, Massachusetts)

This species was seen by Aneptek, but its presence was disputed by Hunt.

Source: Compiled by Ecology and Environment, Inc. 1993.

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2.2.9.2 Wetland Ecosystems

Wetlands are transitional ecosystems that occur between upland (terrestrial) and aquatic environments. Water is the primary factor controlling these habitats and the associated plant and animal communities. Occurring in a wide variety of forms, wetlands normally have three factors in common: dominance of hydrophytes (water tolerant plants), presence of hydric (saturated) soils, and a water table at or near the ground surface for a long enough duration during the growing season to develop anaerobic conditions. The wetland types commonly found in the Annex region include forested wetlands, scrub/shrub wetlands, and emergent (i.e., herbaceous) wetlands. Each of these wetland types and communities is discussed below.

In general, the most abundant type of forested wetland in the region is the bottomland hardwood forest, which occurs on river floodplains and along the edge of many other water bodies throughout the area. Nutrients are constantly being flushed into these systems by periodic flooding. As a result, they are very productive and support an abundant and diverse flora and fauna. The most common bottomland hardwood trees in this region include red maple, American elm, and sycamore. The presence of a variety of woody species, the abundance of fresh water, and the cover attract a diverse array of wildlife. Both aquatic and upland species as well as species specifically adapted to wetlands (e.g., wood duck, mink, and beaver) frequent these types of habitats.

Scrub/shrub wetlands are scattered throughout the region, often forming in areas which were originally cleared for agriculture and then abandoned. Scrub/shrub wetlands represent an intermediate successional stage between emergent and forested wetlands; however, some scrub/shrub wetlands may persist for many years or decades. Vegetation in these areas consists of various species of shrubs such as buttonbush and dogwoods, intermingled with tree seedlings, saplings, emergent grasses, sedges, and rushes. The numerous berry-producing shrubs found in this habitat type provide an excellent food source and serve as cover for songbirds, small mammals, and deer (Martin et al. 1951).

Generally, emergent freshwater wetlands are dominated by grasses and sedges. Plant species commonly found include reed grass, cattail, wild rice, bulrush, spike rush, pickerelweed, arrowhead, smartweed, jewelweed, horsetail, and various species of ferns. Emergent wetland areas are particularly favored by both migrating and breeding waterfowl, which use this habitat's abundant food sources and cover. Other birds common to emergent wetlands include bitterns, herons, rails, plovers, and icterids. Various mammals such as muskrats and beavers are also likely to use this type of wetland.

2.2.9.3 Terrestrial Ecosystems

The terrestrial ecosystems encountered at the Annex primarily include upland forests, but scattered reverting fields and grasslands and developed/disturbed areas can also be found at the Annex. Forests in this region have historically been subjected to heavy logging as a result of commercial use and clearing for agriculture and urban development. Logging

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activities have changed the structure and composition of so many of these areas that virtually no virgin stands remain. Common tree species include red maple, Eastern white pine, Northern red oak, scarlet oak, white oak, quaking aspen, bigtooth aspen, shagbark hickory, American elm, and scotch pine. Numerous additional species are found in fewer numbers throughout the region. The undergrowth consists of various shrubby species, including sassafras, blueberries, and dogwoods. Upland forests support a wide array of songbirds, passerine birds, upland gamebirds, small mammals, and deer.

Reverting fields and grasslands, such as meadows, shrub thickets, and immature forests, are areas in a transitional successional stage between a cleared, open area and an area vegetated with upland forest. These cleared areas, once used for agriculture, were later abandoned and are currently in the process of revegetating. The fruits of the juneberry and dogwood shrubs found here provide an abundant source of food for wildlife. Seeds from many grasses and forbs are used by many species of ground nesting birds, songbirds, and small mammals (Martin *et al.* 1951). Deer are also likely to browse in this habitat type and raptors are known to forage for prey over open areas such as these.

Vegetation in the developed and disturbed areas of the Annex consists mainly of grasses and forbs, maintained lawns, hedgerows, and scattered ornamental trees. Disturbance from human activity makes the wildlife value of this type of habitat relatively low. Species that are likely to occur in developed open areas are sparrows, wrens, grackles, crows, pigeons, rabbits, squirrels, and small rodents. Transient visitors to this habitat include species such as deer, raccoon, opossum, and skunk.

One potential State-listed rare orchid, grass-leaved Ladies' Tress (*Spiranthes vernalis*) was identified by Aneptek Corporation (1991) in the Taylor Drop Zone's unmowed field. However, Hunt (1992) disputed this identification.

2.3 PREVIOUS INVESTIGATIONS

The DoD established the IRP in 1978 to identify, investigate, and clean up contamination from hazardous substances at Federal facilities. IRP activities began in 1980 at the Annex to assess and address the environmental impact of past land usage.

Pursuant to the IRP's mission, the Army has contracted the following organizations to investigate sites at the Annex:

- USATHAMA (now USAEC) detailed record search in 1980;
- U.S. Army Environmental Hygiene Agency (AEHA), Aberdeen Proving Ground, Maryland - hydrogeological and subsurface investigation in 1983;
- Dames and Moore, Inc. RI in 1986;
- Dames and Moore, Inc. Expanded SI (Site P48) in 1990;

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- Goldberg-Zoino and Associates (GZA) Geoenvironmental, Inc. SI, 100-Acres Excessed Land in 1991:
- OHM, Inc. Master Environmental Plan in 1992:
- OHM, Inc. Phase I SI, RI investigation in 1993;
- E & E, Inc. Master Environmental Plan update in 1994;
- OHM, Inc. Phase II RI investigation; and
- E & E, Inc. Phase II Site/Remedial investigation (ongoing).

In addition, the EPA contracted NUS Corporation in 1985 to conduct a PA/SI at the Annex to fulfill CERCLA requirements under their Superfund Field Investigation Team contract.

Several remedial actions have been performed and underground storage tanks (USTs) and drums have been removed from various Annex locations.

2.3.1 Site Assessment by USAEC (USATHAMA 1980)

The Preliminary Installation Site Assessment conducted by USAEC in 1980 was primarily a historic records search of various activities, including disposal, at the Annex that could have resulted in contamination. The site assessment report indicated that certain areas of the Annex may have been contaminated by the following:

- explosive residues,
- laboratory quantities of chemical solvents,
- POLs, and
- other toxic or hazardous materials.

Based on the site assessment research, 11 areas were identified at the Annex as being possibly contaminated by past usage.

2.3.2 Hydrogeological and Subsurface Investigation by the United States Army Environmental Hygiene Agency (1983)

The AEHA conducted a hydrogeological and subsurface investigation of the 11 sites identified in the 1980 study to evaluate the hydrogeologic setting and groundwater quality associated with each location. The final report was prepared for USAEC in May 1983, and includes discussions on:

- geologic features,
- soils characterization,
- groundwater hydrology,

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monitoring well locations.

- · installation of seven monitoring wells, and
- groundwater sampling and analytical results.

The results of the study showed the potential for contamination to be sufficient to justify conducting an RI at the Annex.

2.3.3 Remedial Investigation by Dames and Moore for the Army (1986)

The 1986 investigation was undertaken to further characterize the 11 sites identified in the previous studies by collecting and analyzing groundwater, soil, surface water, and sediment samples. In addition to the 11 sites, Dames and Moore reviewed and studied potential contamination sources in the vicinities of the CFHA, Puffer Pond, and associated streams. The program was designed to accomplish the following:

- identify and characterize environmental contaminants, especially with respect to Puffer Pond, the vicinity of the leach field (Site A11), the food burial site (Site A8), and the CFHA;
- provide additional information on site hydrogeology; and
- assess the potential for contaminant migration.

To obtain supplemental information on the sites, a monitoring well network of 17 wells was established to detect potential contaminant migration within and around the sites.

Based on preliminary data review, additional samples were collected to further evaluate possible soil contamination at the CFHA and surface water and sediment contamination at the leach field (Site A11) and in the Puffer Pond and associated stream area. The presence of anomalous compounds in samples collected from these areas led to their inclusion on the list of suspected sites. Other aspects of the sampling effort have been covered, as relevant, in the site sections.

2.3.4 NUS, Inc., PA and SI of the Annex for EPA Region I

Prior to the final publication of the Dames and Moore RI Report, EPA's Region I Waste Management Division tasked NUS Corporation's FIT to conduct a PA at the Annex in June 1985. The PA included a review of the Dames and Moore Final Draft RI/FS Report. Based on the PA, EPA instructed the FIT to conduct an SI of the Annex. In May 1987, the FIT completed an SI report on the Annex. The SI results were used by EPA to determine that the Annex should be included on the National Priorities List (NPL) of all sites identified under CERCLA as having an immediate and direct potential for impact on human health and the environment. Details on a polychlorinated biphenyls (PCB) spill were considered as key information in the evaluation of the site. The spill occurred in an area designated by the Army as A12, which is just south of A11. Remediation of the PCB spill took place in 1985 and 1986, and the cleanup was approved by MDEP in 1989.

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2.3.5 SI of 100-Acre Parcel of Excessed Natick Lab Annex Property by GZA Geoenvironmental, Inc., for the U.S. Army Corps of Engineers (March 1991)

GZA was asked to conduct an SI at an excessed 100-acre parcel of land, which formerly comprised the north limit of the Natick Laboratory Annex in Maynard, Massachusetts. The study was performed as part of the DERP to determine the presence or absence of chemical contamination that may have resulted from DoD activities since about 1942 at the site. The SI included site walkovers, environmental media sampling, monitoring well installations, and background research.

GZA's background research indicated that the 100-acre area had remained "buffer land" since 1942, undergoing no improvements since that time. Part of the site had been used for an obstacle course, but no documentation of waste dumping or storage at the site was found. GZA conducted a stereoscopic aerial photography review of the site, using photographs generated in 1957, 1986, and 1989. The site area was observed to be increasingly overgrown.

After reviewing background information and observations made during site visits, GZA concluded that there was no evidence of past disposal of chemicals in the previously identified EPA Sites 8a and 8b, nor was there evidence of dumping or other surficial sources of environmental contamination attributable to DoD-related activities in the remaining portions of the area. Laboratory analyses revealed that petroleum hydrocarbons were identified within some soil and sediment samples near the detection limit. These could result from urban runoff. No petroleum hydrocarbons (PHCs) were detected in water samples. Base-neutral acid extractable compounds (BNAs) were identified in trace to low levels in soil and sediment samples, at levels consistent with those normally associated with urban runoff, oil-based insecticides, and residuals from brush or forest fires. Metal levels were elevated, and, while some may be attributable to urban runoff, lead and chromium levels were outside the normally expected range of concentrations typical of hydrogeological conditions in New England.

2.3.6 Expanded Site Inspection (POL Bladder Testing Area — P48) by Dames and Moore, Inc. (March 1991)

The Expanded Site Inspection was conducted to assess the extent of potential soil, groundwater, and surface water contamination at three sites identified by Natick Research Development and Engineering Center, only one of which was at the Annex: the old POL Bladder Testing Area (POL Test Area). The field activities consisted of coordinating a soilgas survey conducted by Northeast Research Institute, Inc. (NERI), to characterize potential soil-gas contamination in the vicinity of the bladder test area.

The soil-gas survey detected the presence of low levels (reported as ion counts) of benzene, toluene, ethylbenzene, and xylenes (BTEX), moderate- to heavy-weight petroleum hydrocarbons, trichloroethene (TCE), and tetrachloroethene (PCE). Because the suspected releases occurred more than 20 years ago, degradation, migration, and dispersal of the contaminants probably occurred, resulting in their widespread distribution and apparently low

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levels. While the identity of the contaminated media and the absolute contaminant concentrations are not known, the low levels of contamination detected in the soil gas do not appear to present a current or future threat to public health or the environment. Dames and Moore suggested that a single monitoring well be installed and sampled to verify the absence of significant contamination and that a limited number of soil samples be analyzed.

2.3.7 Phase I Site, Remedial Investigations by OHM Corporation (January 1994)

OHM Corporation was tasked by the USAEC to perform an SI/RI of the Annex, and asked to conduct record searches, study area reconnaissances, and a field investigation consisting of geophysical surveys, soil-gas surveys, test pit excavations, installation of monitoring wells, and the advancement of soil borings. Sampling activities included soil and sediment sampling, drum removal and confirmatory soil sampling (to confirm that the soil did not have residual contamination at the removal site), surface water and groundwater sampling, transformer sampling, an ecological assessment, and air monitoring. Several facility-wide assessment, inspection, and reconnaissance activities were also performed. As a result of the initial research effort, 68 sites were identified for review, including Sites A1 through A12, previously investigated.

At the conclusion of the OHM SI/RI report, the following recommendations were made: three sites (A4, A7, A9) were recommended for RI/FS, including two associated sites (P8 and P12); two sites were recommended for RIs (P11 and P13); one site (P3) was recommended for an interim remedial action; 23 sites (A1, A2, A6, A8, A11, A12, P2, P6, P10, P16, P22, P23, P28, P31, P36, P37, P38, P39, P40, P41, P43A/B, P54, P56) were recommended for SIs; 18 sites were recommended for confirmatory SIs (A3, A5, A10, P1, P4, P7, P9, P17, P20, P25, P26, P27, P35, P42, P45, P48, P51, P52) and 18 sites were recommended for no further action (P14, P15, P18, P19, P21, P24, P29, P30, P32, P33, P34, P44A/B, P46, P47, P49, P50, P53, P55). Some of these recommendations were altered in subsequent discussions between the Army and regulators.

2.3.8 Phase II Site Investigations by E & E (September 1994)

In the Phase II effort, E & E was initially tasked by USAEC to investigate 38 sites at the Annex. Five of the 38 sites were elevated to RI status, and, on the basis of proximity to each other, were grouped into two RIs and are discussed in this report. For the remaining 33 sites, E & E was tasked to perform 31 SIs, in addition to conducting watershed assessments of the entire Annex. As part of these investigations, E & E conducted record searches; site reconnaissance; and field investigations consisting of geophysical surveys, test pit excavations, hydraulic conductivity slug tests, water level measurements, advancement of soil borings, and installation of monitoring wells. Sampling activities included groundwater, surface water, sediment, surface soil and subsurface soil sampling, and rapid biological assessment. Geotechnical and geophysical data and groundwater and surface water elevations were used to develop a groundwater model for the Annex. After the SIs were complete, 12 sites (A5, P9, P16, P23, P27, P28, P31/P58, P38, P41, P45, P54) were proposed for supplemental SI investigations, five sites (A1, A2, P2, P22, P39) for further (removal) action, four sites (A10, A11, P1, P6) for further action pending results of the supplemental SI effort, and 12 sites for

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no further action (NFA). As a result of discussion between the Army and regulators, eight sites (A6, P26, P40, P42, P43A/B, P48, P56, P57) were accepted for NFA and No Further Action Decision Documents are currently in review.

NFA status is being considered for four other sites: A8/P10, P3, and P52.

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3. FIELD INVESTIGATION AND ANALYTICAL PROCEDURES

The field investigation activities performed at the Annex were designed to follow up on previous site studies and provide information on the nature, extent, and degree of contamination at each site, for each of the seven watersheds and for the Annex as a whole. Data produced will be used for potential treatability studies, risk assessments, and evaluation of remedial alternatives as well as to justify NFA decisions as appropriate. Field investigations performed at the Annex included the following:

- Geophysical surveys using EM ground conductivity radar and magnetometry studies to better define the location of buried drums and material; seismic surveys to assist in well location and to establish depth to bedrock;
- Test pit excavations to define and classify anomalies identified by geophysical surveys and to visually identify subsurface soil contamination;
- Subsurface soil sampling to estimate the horizontal and vertical extent of soil contamination;
- Monitoring well installation with subsequent groundwater sampling to provide data on site groundwater quality;
- Depth-to-water measurements on all new monitoring wells and selected OHM, Dames and Moore, and GZA wells to provide data on head elevation and groundwater flow direction;
- Slug tests to determine hydraulic conductivity, aquifer transmissivity, and the rate of groundwater migration of the overburden aquifer and to assess the feasibility of groundwater remediation;
- Building wipe samples to assess residual contamination within one building;
- Surface soil sampling to determine the potential human health and ecological risk and the extent of contamination, if found;
- Surface water and sediment sampling to determine the extent of contaminant migration by surficial runoff and groundwater discharge;

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• Field survey of stream benthic communities, wetlands, terrestrial fauna, flora, and pond/lake communities to provide data on current ecological conditions;

- Development of a facility-wide groundwater model for the Annex;
 and
- Collection of background soil, surface water, and sediment samples and site-boundary surface water and sediment samples to evaluate the potential for the release of contaminant to the environment from the watersheds at the Annex.

The field work performed at each site and the rationale for sample locations are discussed in the individual RI reports. These sections describe the standard procedures followed for field investigations at the Annex and the related analytical program.

3.1 FIELD PROCEDURES

Field procedures approved for use in this investigation have been described in several previous documents, including the January 1994, Final E & E Field Sampling Plan Addenda (E & E 1994d), and the April 1992, Final OHM Field Sampling Plan (OHM 1992a). For further information related to field procedures, please refer to these documents. This section briefly describes the procedures E & E followed during field investigations at the Annex. Any Annex-wide deviations from the approved procedures are noted in this section and site-specific deviations are explained in the individual RI volumes.

3.1.1 Geophysical Surveys

Geophysical surveys performed at the RI sites included EM ground conductivity radar and magnetometry studies to better define the location of soil disturbances and buried material. Seismic surveys assisted in well location and established depth to bedrock, groundwater elevations, and additional stratigraphic information. The specific field work performed at each study area is described in the individual RI volumes, and a more detailed geophysical report in presented in Appendix E.

3.1.1.1 Seismic Surveys

Seismic subsurface exploration works by using the basic physics of wave propagation to calculate the intensity of sound (seismic) waves reflected off or fracted by materials of different density. The components for acquiring seismic data are as follows: the shot, defined as the energy source that generates seismic sound waves to propagate through the subsurface; the receiver, which is the instrument that converts ground motion caused by the seismic waves into an electric signal; and the recorder, which is the instrument that converts and stores the signals from the receiver into positive or negative integers of varying amplitude that correlate with the ground motion intensity and direction (up or down) at that receiver.

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An ABEM MINILOC seismograph was used to collect the seismic data, following the procedure below:

- Seismic line locations were selected after consideration of surface topography, ground cover, and necessary ties with other lines in and around the sites.
- Three geophones were "planted" on the seismic line one at each end and the third in the middle. Thirty-six shotpoints were evenly spaced between the two end geophones, with each shot recorded as a single trace in each of the three geophone records. Shot energy was created by using a 12-pound sledge hammer to strike a rubberized plastic plate, with 3 to 5 shots "stacked" at each shotpoint location.
- Data were examined by the geophysicist following completion of all shots, and if satisfactory, downloaded to a laptop computer.
- Field interpretation was run on select lines to insure data quality and check acquisition parameters, using the MINILOC built-in software.
- Final interpretation was performed using SEIS REFA, a software package from OYO Corporation.

3.1.1.2 Electromagnetic Conductivity Surveys

The instrument used for this EM study was the Geonics EM31 Terrain Conductivity Meter. The EM31 continuously measures the terrain conductivity of the material beneath and immediately surrounding it. The EM31 consists of a small control box with two opposing booms extending approximately 5-1/2 feet from the box. A transmitter coil is attached to the end of one boom and a receiver coil is attached to the end of the other boom. The coils are co-planar with the instrument dipole perpendicular to the ground. The depth of investigation for the EM31 at the Annex sites was approximately 18 feet for the vertical dipole and 9 feet for the horizontal dipole. The different dipoles are obtained by rotating the instrument 90 degrees about the axis through the booms. All conductivity readings from the EM31 are in millimhos per meter (mmhos/m). Data from the survey are presented in Appendix E.

Two basic methods of conducting an EM survey were used at the Annex: a gridded survey and a reconnaissance (recon) survey. In a gridded survey, data are collected and recorded at stations that have been laid out by some form of land survey method. An EM recon survey can be considered a real-time analysis of the data, with the operator continuously watching the EM31 for any readings that deviate from background. In this type of survey, results, but not data, are usually recorded. This kind of survey was used when the exploration targets were large or shallow, highly conductive objects such as USTs or pipes.

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3.1.1.3 Magnetometry Surveys

An EG&G G856 proton precession magnetometer was used in the Annex survey. This instrument provides readings that are a measurement of the Earth's total magnetic field, expressed in gammas. The presence of ferrous metals will cause anomalous readings from the local background reading, thus locating potential contaminants.

The first step in the magnetometry surveys was the establishment of stations (usually on a grid) where readings would be taken. A base station was established at a background location and an initial reading taken. Readings were then taken and recorded, along with the station location, with a final base station reading at the end of the day, or at survey completion. The operator periodically returned to the base station to record a new reading and the time it was taken. These base station readings were used to check against any ongoing magnetic storms or to correct the survey data for diurnal variations. Any observable metal in the survey area was logged and located so that any correlation with magnetic anomalies could be determined later.

Data were reduced, starting with diurnal variations. The base station readings were adjusted to a baseline value and these adjustments interpolated and applied to the intervening data readings. These data were then posted on a base map and contoured. Appendix E contains data from the surveys.

3.1.2 Monitoring Well Installation

Eleven new monitoring wells were installed to monitor the groundwater at the RI sites. Boreholes were nominally 8 inches in diameter and wells were screened in unconsolidated material.

All wells were advanced using hollow stem augers to approximately 3 feet below the water table. The soil samples were collected at 5-foot intervals with a hammer-driven, 2-inch by 2-foot split spoon. Samples were screened with an OVA, and the soil was classified and logged by an E & E geologist. One archive sample from each split spoon was collected for storage on-site. Samples were also collected from a split spoon in the screened interval for chemical and geotechnical analyses. Analyses included Total Organic Carbon (TOC) content and grain size distribution. Atterberg limits were only tested on appropriate samples (see Appendix D and Section 3.1.5.1).

All wells were constructed with USAEC-approved materials. The well casing and screens were flush-threaded, 4-inch inside diameter (ID), schedule 40, polyvinyl chloride (PVC). All screens were No. 10 (0.010 inches) slot. No glue or solvents were used on the casing and screen. A threaded cap was placed on the bottom of each screen and expandable caps were placed on the top of each riser.

No. 10 sand was placed as a filter pack from the bottom of the well to a point not less than 5 feet above the top of the screen. Then, a 5-foot-thick, bentonite seal was placed on top of the filter pack and allowed to hydrate. A 5-percent bentonite/Portland cement was

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placed in the well annulus by tremie pipe to the surface. A 6-inch-diameter, steel, protective surface casing was placed in the grout column and a mortar collar was then poured between the protective casing and the riser. Finally, four steel bumper posts were placed around each well. Appendix B contains well construction details for all newly installed monitoring wells. Completed bore logs and well construction logs were sent at the end of each field date to USAEC site geologists.

When conditions in the field required construction parameters to be changed, the USAEC representative was consulted prior to any deviation from the work plan. For example, groundwater was very near the surface at some locations and placement of the screen across the top of the water table required the use of an annular seal of less than 5 feet and, in some cases, a filter pack that extended 1.5 feet, as opposed to two feet above the top of the screen. Well construction details are presented in Appendix B.

All drilling equipment was steam-cleaned to remove oil, grease, and other matter prior to the start of on-site drilling. Rinse water was containerized in drums. All well screens and casings were free of foreign matter and washed with approved water prior to use. Specifications for material, sand, and equipment used in monitoring well installation were USAEC approved.

3.1.3 Monitoring Well Development

Before well development, the static water level was measured from the top of the casing and recorded. Conductivity, pH, turbidity, and temperature were measured and recorded, before, twice during, and at completion of well development. Monitoring wells were developed between 48 hours and seven days after installation.

Well development was accomplished with a submersible pump for wells with adequate recharge or with stainless-steel, bottom-filling bailers for slow-recharging wells. The bottom-filling bailer was used to remove sediment from the wells prior to insertion of the submersible pump. All of the development equipment was decontaminated with USAEC-approved water prior to insertion in each well to avoid cross-contamination.

Each well with adequate recharge was pumped until it yielded turbid-free water or was stabilized in terms of pH, conductivity, and/or temperature. During development, water was removed throughout the entire water column by periodically lowering and raising the pump in the well. The number of linear feet of static water (difference between static water level and total depth of well) was calculated and static water volume was estimated using the following formula:

V (in gallons) = 5.8752 (conversion factor for gallons) x C^2 x H

C = Casing diameter in feet

H = Height of water column in feet

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At a minimum, the standing water volume in the well was removed five times. whenever recharge rates allowed. Also, where drilling water was introduced into and lost in the well, an additional volume (five times the measured amount of lost water) was removed.

All development fluids were handled, characterized, and containerized by using the procedures outlined in Section 3.1.9 of this report.

3.1.4 Hydrogeologic Assessment

Hydrogeologic, or groundwater, assessment of the RI sites involved the following activities:

- Performing slug tests on all newly installed E & E wells to derive hydraulic conductivity values for the unconfined outwash aquifers underlying the sites;
- Surveying wells and surface water gauges and collecting water level data to derive hydraulic gradient and directions of flow;
- Collecting water quality data to evaluate natural and contaminant groundwater chemistry;
- Developing an Annex-wide groundwater elevation contour map;
- Estimating recharge, discharge, evapo-transpiration, and runoff, and incorporation of all appropriate data into an Annex-wide threedimensional groundwater model; and
- Calibrating the model and conducting sensitivity analyses to assess the most important factors controlling groundwater hydraulics.

3.1.4.1 Hydraulic Conductivity Slug Testing

Slug testing is performed to derive a preliminary characterization of the hydraulic conductivity and/or transmissivity of the aquifer. All new wells were subjected to slug testing to determine hydraulic conductivity of the aquifer. The method used for displacing water in the wells consisted of lowering a sealed PVC pipe, weighted with sand (the "slug"), into the well until the water level stabilized before rapidly withdrawing the slug. Water-level response was collected using an electronic data logger (e.g., Hermit 1000® or Hermit 2000®) manufactured by INSitu, Inc. and pressure transducer system (e.g., 10 or 20 psi transducer).

Slug test response data were analyzed using the method of Bouwer and Rice (1976), updated in 1989, or Cooper et al. (1967). The method selected was determined by the hydrogeological condition of the aquifer and assumptions inherent for each method.

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3.1.4.2 Groundwater Elevations and Well Location Survey

Each of the 11 newly installed wells was surveyed by a licensed surveyor. The elevations of each well at ground surface, at the top of the riser, and at the top of the protective well casing were surveyed to ± 0.05 feet, and referenced to the Massachusetts State Plane Coordinate System of 1983 and the National Vertical Datum of 1983. The survey data were recorded in accordance with USAEC geotechnical requirements. Monitoring wells were located on the Annex base map. Map coordinates were transferred to the USAEC IRDMIS. The coordinates were first transformed to the former Massachusetts coordinate system of 1929, using CORPSCON (version 3.01 software) by the National Oceanographic and Atmospheric Administration (NOAA). These data supported the development of the Annexwide groundwater elevation contour map and were used in development of the groundwater model.

3.1.4.3 Groundwater Modeling

A detailed groundwater flow model of the Annex was developed based on the following data:

- Geologic data from the USGS geologic mapping and from E & E mapping and reports,
- All lithologic data,
- Bedrock elevations from borehole and seismic results.
- Topography (digital elevation model from USGS or MDEP photography),
- Stream and river locations and surface water gauges,
- Wetland areas,
- Slug and pump testing results,
- Pumpage from on-site and nearby municipal wells, and
- Well water levels (on diskettes).

A three-dimensional groundwater flow model was set up and calibrated. The USGS MODFLOW model was used. The modeling is of two layers that encompass all of the Annex - the unconsolidated glacial aquifer and the upper part of the bedrock aquifer. The area modeled is approximately 3 by 3.5 miles. Model sites were selected as they relate to boundary conditions, such as drainage divides and water bodies. Grid spacing is approximately 250 feet.

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Hydrogeological functions simulated in the model included recharge, pumpage, and groundwater runoff to streams and ponds. Groundwater runoff in a perennial surface water stream on the Annex is simulated using the stream routing package MODFLOW. The model is calibrated using a set of monitoring-well water levels. These water-level measurement were taken on 13 September and 3 December 1993, when all wells and staff gauges were measured at one time.

A sensitivity analysis was performed using three parameters varied from their calibrated estimate (both higher and lower). A full description of the groundwater model is included as Appendix H of this report.

3.1.5 Sampling Procedures

This section discusses the procedures followed by E & E in the performance of field sample collection tasks. These procedures were established and are discussed in detail in the *Field Sampling Plan Addendum, Phase II Site Inspections, Remedial Investigations* (E & E 1994d).

3.1.5.1 Geotechnical Samples

USAEC requires that physical soil testing be conducted on 10 to 20 percent of the soil samples collected for lithological description and that lithological samples be collected at 5-foot intervals. Those samples not sent for analysis are retained by the installation as archive samples. The RI drilling program generated geotechnical samples which were subjected to various soil engineering tests. Procedures followed for geotechnical samples are noted below:

- Soil samples were collected for lithological description during well installation and soil borings.
- Sieve grain-size analysis was performed in most cases on one sample collected at each well location and at each sediment location and on selected surface soil samples collected at sites in each watershed. At only one borehole (E3-A12-B01) was a sample collected for sieve grain-size analysis. Samples were subsequently defined using the Unified Soil Classification System (USCS).
- Atterberg Limits analysis (ASTM D4318) was requested for all grain-size samples and performed when possible. The index of plasticity could be determined only on samples with sufficient finegrained material to allow such a test. The laboratory made that determination at the time of testing. Appendix D provides a summary of all the geotechnical samples submitted for analysis.

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3.1.5.2 Subsurface Soil Sampling

Test pits were excavated with a backhoe at Sites P13 and P36 to determine areas of possible contamination. Excavations were in areas identified by magnetometer or electromagnetic surveys or where research indicated subsurface contamination might exist. An E & E geologist classified soil and collected a maximum of two samples from each test pit. Procedures followed for test pit excavations at the Annex are noted below:

- Test pits were approximately 10 feet long, 3 feet wide, and 6 to 12 feet deep. Test pit excavations were performed in Level D personal protective equipment (PPE) at all sites. Final test pit dimensions were adjusted in the field when further digging was required to assess the extent of contamination.
- At each study area where test pit excavations were performed, a
 temporary decontamination area was constructed for steam cleaning
 the backhoe bucket. The decontamination water was containerized
 by pumping from the decontamination pad to a 55-gallon drum
 mounted on a flat bed truck. The drums were then transported to the
 main decontamination area, secured, labeled, and stored with the
 other drums of decontamination water.
- After completion of field investigation activities, the drums were stored in the warehouse at Site P13 with other drums containing investigation-derived wastes for future disposition pending the outcome of the site-specific investigations.
- If required, grab samples were collected from each test pit. Volatile
 organics grab samples were collected first from the backhoe bucket at
 each of two depths sampled. Soil was then collected from the
 backhoe bucket with a QC-compliant, stainless-steel spoon. The
 remaining composite samples were collected after the soil from each
 interval was homogenized in aluminum pie tins.
- Each test pit was backfilled after the final soil sample was collected and the soil classification completed. All excavated material was returned to test pits during backfilling, as no material was encountered that posed an immediate hazard to the environment.

Subsurface soil samples were collected and analyzed to determine the vertical and horizontal extent of contamination in the subsurface. Presented below are the procedures followed for subsurface soil sampling at the Annex:

 Boreholes were drilled using hollow stem augers. All borings were completed to a depth just below the water table (not greater than 20 feet). Refer to bore logs in Appendix A for soil classification data.

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• A 2-foot long, 2-inch diameter, stainless-steel split-spoon was driven at 5-foot intervals from the ground surface to just below the water table, using a 140-pound hammer with a 30-inch free fall. A 3-inch diameter split-spoon was used when additional soil volume was required for QC samples. If low sample recovery or split-spoon refusal was encountered, an additional split-spoon was driven within the auger hole at the same interval, at a point offset from the original split-spoon location.

- Samples for analysis were collected from one split-spoon recovered above the water table and one split-spoon recovered within the water table, at each borehole location. This was done to assess soil infiltration rates in the vadose zone and soil conductivities in the saturated zone.
- A gasoline-fueled power auger was used to conduct subsurface soil sampling in areas that could not be reached with a drill rig or a backhoe. A 6-inch diameter, solid-stem auger was used to achieve a maximum depth of 5 feet. Samples were taken directly from the cutting collected at the 1.5 and 4.5 foot depths.
- Samples were collected with a clean stainless-steel spoon. The soil
 for the composite samples was homogenized in aluminum pie tins
 after each volatile organic grab sample was collected.
- Any rocks, twigs, leaves, or other debris that were not representative was removed from samples before homogenization.
- Sample bottles were labeled with indelible ink and sealed with custody tape. Chain-of-custody forms were completed, and samples were placed in a temperature-controlled chest and delivered to the laboratory.
- All boreholes were backfilled with Portland cement mixed with 5 percent bentonite (grout). The grout was mixed by hand in a 55-gallon drum and poured into the borehole until it was level with the ground surface. Grout in each borehole was allowed to settle overnight. After settling, additional grout was added to each hole until once again level with the ground surface. Power-auger boreholes were backfilled with drill cuttings.

3.1.5.3 Surface Soil Sampling

Surface soil samples were collected at the RI sites to characterize background conditions, determine the nature and extent of contamination, evaluate potential human health

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and ecological risks, and to assess the potential migration of contaminants. The procedures followed for surface soil sampling are presented below:

- Each location was staked and marked for future reference and sample locations were plotted on the site maps. The distance and direction from a reference point to a sampling point was also recorded.
- Personnel took care to use a new set of clean, disposable gloves when handling sample bottles.
- Surface soil samples were collected from a depth of 0 to 6 inches at each sample location, using a disposable stainless steel spoon. Care was taken to avoid the collection of leaves, roots, sticks, and rocks.
- All samples, except those for volatile organics, were homogenized in a disposable pie tin before filling the appropriate container.
- Samples for volatile organics were collected first and immediately placed in the appropriate containers before homogenizing the sample.
- Any observed physical characteristic of the soil (e.g., color, odor, physical state) was recorded in the site log book.
- Sample bottles were labeled with indelible ink protected with clear tape. Custody seals were placed on all jars. Chain-of-custody forms were completed, and samples were packaged in a temperaturecontrolled chest and shipped to the laboratory.

3.1.5.4 Field Screening

Field screening for PCBs in subsurface and surface soil samples was conducted at Site A12. Field testing of surface soil and subsurface soil borings was conducted using the ENSYS PCB RISc® Soil Test System (Ensys Inc., Research Triangle Park, NC). The system is based on an immunoassay/photometric detection method developed to qualitatively identify 95 percent of samples that are free of PCBs at concentrations greater than 1 part per million (ppm). The system control is established through the use of 1 ppm and 10 ppm standards.

The PCB screening procedure consists of three phases. Phase 1, Preparation and Extraction of the Sample, involves the weighing, extraction, and filtration of each sample to be tested. Phase 2, Sample and Standard Preparation, involves the quantitative dilution of the samples and standards to be used. Phase 3, The Immunoassay, entails incubation, enzyme addition, color development, and photometric measurement of the results. The presence of PCBs is determined by comparing the photometer reading of the standard to that of the samples at two dilution levels. Since an inverse relationship exists between PCB concentration and color intensity with this method, the lighter the color of the solution, the higher the concentration of the PCBs. Accordingly, readings of negative or zero indicate the

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presence of PCBs. When tested at two different solution concentrations, the relative concentration of the PCBs is determined qualitatively.

3.1.5.5 PCB Building Wipe Sampling

Building wipe samples were collected in one building (T104) to assess the extent of residual PCB contamination located at this location. A total of 10 wipe samples were collected in April 1994. Sampling locations were identified during a building survey of existing equipment and potential PCB sources conducted prior to the sampling event.

Wipe samples were collected from a 100 cm² area at each sample location through use of a 1/8-inch Teflon sheeting template with a 10 cm by 10 cm square hole. The template was cleaned with pesticide grade hexane prior to the sampling event. The following procedures were utilized during wipe sample collection:

- Cotton gauze swabs were prepared by saturating the swabs in a precleaned 4 ounce glass jar partially filled with hexane;
- The template was wrapped in aluminum foil prior to the collection of each new sample. The foil was removed after the collection of the samples and new foil was applied for the collection of the next sample;
- The template was placed on the area to be sampled. A single swab was removed from the hexane jar;
- The template hole area was wiped quickly using firm uniform pressure and a clockwise wiping motion around the perimeter and parallel strokes across the remaining area;
- The swab was then placed in a pre-cleaned 4-ounce glass jar and the Teflon-lined lid was secured on the jar;
- Each jar was clearly labelled with the appropriate sample information, protected with clear tape and then custody sealed.
 Chain of custody forms were completed and samples were packaged in a temperature-controlled chest and shipped to the laboratory;
- Sample collection information was noted in the field logbook and sample locations were identified after all wipes had been collected through the use of fluorescent paint;
- The template, aluminum foil, and swabs were only handled with field sampling gloves or with dedicated stainless steel tweezers that were cleaned after each sample;

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 Since hexane acts as a carrier to a number of semivolatile organic compounds, all wipe sampling was conducted in Level C protection, in accordance with recommendations from the health and safety coordinator.

3.1.5.6 Groundwater Sampling

Groundwater samples were collected to determine groundwater quality and assess the need for future groundwater remedial action. Groundwater samples were collected from a total of 16 wells -- 11 newly installed wells and 5 already-installed wells. Two rounds of groundwater sampling were performed as described for each RI site in Section 2 of the RI Volumes II and III. Monitoring wells and staff gauge locations at the Annex are presented in the Plate in a pocket at the end of this volume. As required by USAEC Geotechnical Specifications (USATHAMA 1987), the following procedures for groundwater sampling were used:

- A minimum period of two weeks was allowed between well development and sampling.
- Water-quality field instruments, such as the Horiba® U-10 Water Quality Checker, were calibrated daily before samples were drawn.
- Equipment used to measure groundwater conditions was decontaminated before the initial use and before proceeding to a new location.
- Clean plastic sheeting was spread around wells to protect the sampling equipment from ground surface contamination. New protective sheeting was used at each sampling location.
- The depth from the top of the well casing (not the protective casing)
 to the top of the water was measured to the nearest 0.01 feet with an
 electronic water level indicator and the depth was recorded in the
 sampling logbook.
- The depth from the top of the casing to the bottom of the sediment/water interface was measured and recorded. In cases where the well was dry, the depth of the well was measured.
- The height of the water column was obtained by subtracting the depth to top of the water from the depth to the bottom of the sediment/water interface.
- A quantity of water equal to five times the calculated volume of water in the well, including the saturated annulus, was removed from the well. The wells were purged using a 2-inch diameter

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submersible pump, or a stainless steel bailer, or polyethylene disposable bailers.

- Samples of groundwater were collected and measured for temperature, specific conductance, pH, and turbidity before purging. at regular intervals during purging, and after each well volume was evacuated. Purging was considered to be complete when turbidity measurements reached 50 nephelometric turbidity units (NTUs) and remained constant. It should be noted that constant measurements could be obtained when NTU measurements were still one or even two orders of magnitude greater than the EPA Region I recommended criterion of 5 to 10 NTUs (OHM 1994).
- When a well went dry during pumping or bailing, and the recovery rate was rapid, the well was allowed to recover to its original level and evacuated a second time before sampling. If recovery was very slow, samples were obtained as soon as sufficient water was available.
- Purge water was handled and characterized in accordance with the methods and procedures described in Section 3.1.9.
- Samples for chemical analysis were obtained immediately after pumping or bailing was completed. For slow recovery wells, the sample was collected immediately after sufficient volume was available.
- Sample bottles were triple-rinsed with the water being sampled before filling the bottle with the sample to be analyzed. Bottles for filtered samples were rinsed with filtered sample water and bottles for unfiltered samples were rinsed with unfiltered water.
- Care was taken by personnel to use a new set of clean, disposable gloves when handling sample bottles.
- Samples were preserved in the field immediately after sampling. Samples were collected using a disposable, bottom-loading polyethylene bailer secured with nylon or polyethylene rope. Samples were poured directly from the bailer into the sample container.
- When sampling for volatile compounds, the preservative was added first and vials were filled without agitation or splashing to avoid loss of analyte. No air space was left in the vials.

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For other analyses, bottles were filled with the sample and the
preservative was added. The pH of samples was ensured by filling
an extra glass jar or polyethylene bottle and testing the preserved
sample against pH paper. After pH testing was complete, care was
taken to avoid air bubbles collecting in the sample volatile organic
analysis (VOA) vials.

- Field logs were maintained with the site name, well number, date, time, depth to water, purge method, volume purged, sampling method, sample appearance, weather conditions, and any relevant observations.
- Sample bottles were identified with computer-generated bar code labels or with indelible ink, protected with clear tape, and then custody seals were placed over the tops of the bottles. Chain-ofcustody forms were completed and samples were packaged in a temperature-controlled chest and shipped to the laboratory.

Groundwater Filtering for TAL Metals

Filtered samples were collected for metals analysis from all wells at the RI sites, using an in-line filter and a centrifugal pump, as described below.

• The in-line filter (0.45 micron pore size) is attached to a 1-foot to 2-foot piece of Tygon® tubing. Prior to collecting the sample, 100 milliliters (mls) of 10 percent nitric acid solution are drawn through the tubing and filter. The tubing and filter are then rinsed with 1 liter of deionized water by drawing the water through the apparatus. The Tygon® tube is placed in the unfiltered container and the filter outlet is set to drain into an unrinsed, 1-liter polyethylene container. The pump is turned on and three 30-ml portions of filtrate are used to rinse the sample container. The sample is then collected by starting the pump and collecting the sample in the rinsed, 1-liter polyethylene container. The filtered sample is then preserved with nitric acid to a pH less than 2.

3.1.5.7 Surface Water and Sediment Sampling

Surface water and sediment samples were collected in several areas of the Annex to determine background levels, assess potential health risks, and determine the nature and extent of contamination. Surface water and sediment locations are presented in the Plate in a back pocket of this volume. Dissolved oxygen, pH, temperature, and specific conductivity were measured immediately before surface water sampling with a Horiba® RU10 water quality meter. Sediment samples were collected in areas of low flow/turbulence or deposition and an effort was made to collect samples of greater than 30 percent solids by decanting excess water, as required by USAEC guidance. TOC and grain-size analyses were performed on all

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sediment samples. The procedures followed for surface water/sediment sampling at the Annex are noted below:

- Surface water samples were collected in conjunction with sediment samples except when the location was void of standing water.
- Before sampling, equipment was triple-rinsed with stream water downgradient from the sampling points, taking care not to disturb sediments.
- For surface water samples, the sample bottles were triple-rinsed with the water being sampled before filling the bottle with the sample to be analyzed.
- Sample collection began at the furthest downgradient location and proceeded to the upgradient locations.
- Sample vials were only handled with a new set of clean, disposable gloves.
- At each sample location, the surface water sample was collected prior to the sediment sample.
- The surface water sample was collected by immersing the sample bottle in the surface water body, when possible. When the surface water body was too shallow to fill the sample container by immersion, a new, clean, small, glass bottle was used to fill the container. Care was taken to minimize the collection of floating debris, suspended solids, or sediment.
- Sediment samples were collected using a disposable stainless steel spoon. Volatile organics samples were taken first. All other samples were homogenized in a dedicated disposable aluminum pie tin before putting them in their appropriate containers. Care was taken to avoid the collection of leaves, roots, sticks, and rocks.
- When surface water samples for volatile organics were collected, the vials were filled without agitation or splashing to avoid loss of analyte. No air space was left in the vials.
- Surface water samples were preserved in the field immediately after sampling. Specific sample preservation requirements are presented in Section 3.1.7. For VOA, preservatives were added to samples prior to filling the bottle. For other analyses, the bottles were filled with the sample, and then preservatives were added. The pH of

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samples was ensured by filling and preserving an extra bottle for each analyte before testing with pH paper.

- Physical characteristics of the sample media were recorded on the field sample collection report.
- Sample bottles were labeled with bar codes or indelible ink and protected with clear tape. A custody seal was placed over the top of the bottles. Chain-of-custody forms were completed and samples were packaged in a temperature-controlled chest and shipped to the laboratory.
- Each location was staked or flagged and marked for future reference.
 Sample locations were plotted on the site maps. The distance and direction from a reference point to a sampling point was also recorded.

3.1.6 Ecological Investigations

To identify ecological receptors, E & E conducted several field surveys throughout the Annex. In May 1993, a rapid bioassessment was conducted in streams within the Annex; in July 1993, a detailed field survey was conducted at sites P11, P13, P36, P37, and A12; and in November 1993, a bioaccumulation fish study was conducted in Puffer Pond and a comparable off-site pond. Ministers Pond, across the Assabet River in the Town of Stow, was chosen. In addition, a thorough literature study of the existing environment in the general vicinity of the remaining E & E sites within the Annex was conducted. The following provides a brief description of the procedures for these various studies.

3.1.6.1 Ecological Characterization

An ecological characterization of the P11/P13 and A12/P36/P37 sites was used to provide information for the baseline risk assessment (for ecological risks). The primary objective of the ecological characterization was to identify and evaluate existing aquatic, terrestrial, and wetland communities. However, other objectives included mapping and describing plant communities within each site, observing wildlife species present in the vicinity of each site, identifying and evaluating significant ecological resources that could be potentially impacted by contamination from each site, and noting evidence of plant or animal stress that may be a result of site contamination. Emphasis was placed on sensitive environments or species that may come in contact with site contamination. These included State- or federally-designated wetlands and other critical habitats, as well as specific species of concern. Based on E & E's preliminary evaluation of available information on site ecology and a site visit, the ecological resources potentially impacted by the sites were identified for further characterization. These resources included aquatic and wetland communities in the vicinity of each site, as well as terrestrial vegetation and wildlife species living on or in the vicinity of each site.

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Ecological characterization of each site was based on collection and analysis of existing site data in conjunction with a field investigation of each site. Field investigations were completed by E & E biologists during June 1993.

Prior to the initiation of fieldwork, the appropriate State and Federal agencies were consulted to determine if any rare, threatened, or endangered species or specially designated ecosystems occur on or near the sites, and to establish if any recreationally important fish species occur in Marlboro Brook or Honey Brook. In addition, the Fort Devens Natural Resource Office was consulted for site-specific information on protected and recreationally-important species, as well as for general information on site vegetation, fish, and wildlife.

Standard reference materials, including literature and map resources were reviewed prior to the initiation of fieldwork. These resources included U.S. Army site maps, U.S. Army aerial photographs, USGS topography quadrangle maps, United States Fish and Wildlife Service (USFWS) quadrangle National Wetlands Inventory (NWI) maps, the *Atlas of Estimated Habitats of State-Listed Rare Wetlands Wildlife* (MNHESP 1992), and soil surveys of Middlesex County (USDA SCS 1991; USDA SCS 1989).

The reference information was supplemented by a field ecological survey at each site. This survey included a wetland delineation and functional assessment. Wetlands were delineated using procedures described in the United States Army Corps of Engineers Wetland Delineation Manual (USACE 1987) and the New England Division of the USACE wetland delineation guidance document (USACE 1991). Vegetation, soils, and hydrology were sampled at one wetland point and one adjacent upland point for each wetland plant community. The jurisdictional boundaries of federally-regulated wetlands were flagged on site. Jurisdictional boundaries of state-regulated wetlands frequently are different than boundaries of federally-regulated wetlands, because Massachusetts defines wetlands on the basis of vegetation and hydrology only. For this reason, wetland boundaries flagged on site may not correspond to jurisdictional boundaries of state-regulated wetlands.

Wetland functions were assessed for wetlands associated with each site using Wetland Inventory Data forms (Hollands and McGee 1985). These forms were designed in response to requirements promulgated under the Massachusetts Protection Act (MGL chapter 131, Section 40) to assess the functions of wetlands.

In addition to the wetland delineation, the ecological survey of the site included a walkover survey. At each site, vegetation cover type boundaries were identified and mapped. Each cover type was traversed and described in terms of plant species composition, vegetation structure, edaphic conditions, and land use. Dominant species in the overstory, understory, and herbaceous layers were identified. In forest communities, basal areas, diameter at breast height, and average height for sample trees were also recorded. At each of the AOC sites, vegetation cover types were mapped using information from the survey, agency contacts, and aerial photographs. Indications of possible stress due to contamination, such as sparse or dead vegetation, were also noted, along with observations of potential wildlife utilization of the sites as habitat or of potentially contaminated seeps as drinking water sources.

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Wildlife use of each site was evaluated using literature sources as well as field observations. Species lists were generated by reviewing *New England Wildlife: Habitat, Natural History, and Distribution* (DeGraaf and Rudis 1986) for relatively common species that occur within Middlesex County, Massachusetts. These species lists were augmented by wildlife sightings made during the field surveys. Wildlife sightings included direct observations as well as identifications based on vocalizations, tracks, burrows, browse, and scat. General wildlife values (e.g., food and cover availability) of each cover type were also noted.

3.1.6.2 Rapid Bioassessment

Rapid Bioassessment Protocol II (RBA II) is a method of determining, over short periods of time, with moderate field effort, the biological condition of a stream or river, and whether or not the system is impaired from its natural state. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish (USEPA 1989e) as set forth by the EPA (EPA/444/4-89/001), was used on aquatic macroinvertebrate communities in selected stream points in Honey Brook and Marlboro Brook. For a full description of the RBA study conducted at the Annex, please refer to Appendix L.

3.1.7 Sample Collection, Preservation, and Handling

During field investigative work, care was taken to adhere to the standardized sample collection protocols set forth in the E & E Sudbury Training Annex Quality Assurance Project Plan (E & E 1994f). Sample collection procedures were as follows:

- Prior to mobilization to the sampling site, the appropriate number and type of precleaned containers were selected and the containers were labeled with the appropriate preprinted labels.
- Upon the sampler's arrival at the sampling location, the time, date, and sampler's initials were recorded on the preprinted label with waterproof ink and the label covered with clear tape for protection.
- Bottles to be used for water samples were then triple-rinsed with sample water to saturate the physical and chemical binding sites on the inner surfaces of the bottles to prevent these sites from removing analytes from solution. An exception to this procedure was containers used for VOC samples, which were not triple-rinsed; they were collected prior to the rinsing of any other containers. During sampling for filtered metals, the polyethylene bottle was triple-rinsed with filtered water to insure that no suspended solids were introduced into the sample bottle.
- To prepare for preservation of VOA water samples, a separate test bottle was used to test the amount of preservation needed to lower the pH of the sample to below a pH of 2. This was accomplished by

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adding an appropriate amount of preservative to the sample bottle, capping and shaking the container, and then testing with pH paper. Preservation for other samples was accomplished by using a standard of 2 ml of preservative and then checking with pH paper and adjusting as necessary.

- Samples were then collected according to the following general sample analysis priorities. For water samples: total petroleum hydrocarbons (TPHC), TCL BNAs, TCL pesticides/PCBs, herbicides, explosives, organophosphorus pesticides, anions, and TAL metals (unfiltered and filtered). For soils: TAL metals, TPHC, and TOC; explosives, TCL BNAs, and TCL pesticides/PCBs; and grain size and Atterberg limits (if applicable). This sampling scheme was also subject to the priority of the analytes of concern at the site and the standard operating procedures of the laboratory.
- After collection of each sample bottle, the appropriate amount of
 preservative was added to water samples, and the bottle or jar was
 then wiped clean and placed in an appropriate container for transport
 back to the field base, where each sample was placed in an ice cooler
 to lower the sample's temperature to 4 degrees Celsius or below.

3.1.8 Decontamination Program

The USAF well at the USAF Weather Science Radar Laboratory was selected as the approved water source for decontamination of equipment at the Annex. In order to satisfy USAEC requirements, the deep bedrock well was sampled in September 1993 to characterize water quality. The sampling results verified that no contaminants were introduced to the water used during decontamination. The well was analyzed for TCL organics, TAL metals, explosives, TPHC, and nitrogen as nitrites and nitrates. Samples were also collected from this well by OHM in July and November 1992, to satisfy USAEC requirements. No contaminants were detected during analysis of these samples.

Sampling methods and equipment were chosen to minimize decontamination requirements and prevent the possibility of cross-contamination. Non-disposable equipment was decontaminated between discrete sampling locations. All drilling equipment was decontaminated prior to drilling, after drilling each monitoring well or borehole, and after the completion of all monitoring wells and boreholes. Specific attention was given to the drilling assembly and augers. PVC casing and screens were kept in sealed containers and cleaned with a high-pressure washer prior to use. Drilling equipment decontamination included the following:

high-pressure cleaning;

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- scrubbing with brushes, if visible contamination remained on equipment; and
- high-pressure rinsing.

Split-spoon and other non-disposable sampling equipment were also decontaminated between each sampling event. Sampling equipment decontamination included:

- high-pressure cleaning (for split-spoon),
- scrubbing with brushes,
- triple rinsing with USAEC-approved water, and
- air drying.

A temporary decontamination pad was constructed by the drilling subcontractor near the E & E site trailer at the main gate. The specifications for the pad required using an approximately 12-foot by 12-foot area with a defined perimeter approximately 6 inches high, lined with heavy plastic sheeting to collect decontamination waters and sediments. The primary purpose of the pad was to decontaminate heavy equipment such as augers, well casings, and screens.

3.1.9 Control and Disposal of Investigation-Derived Wastes

In the course of collecting environmental samples and conducting field work at the Annex, E & E field personnel generated different types of potentially contaminated investigation-derived wastes, including: soil cuttings, drilling muds, purged groundwater, disposable sampling equipment, and disposable PPE. Protocol for controlling and disposing of such wastes was developed by Fort Devens, USAEC, and EPA for the Fort Devens NPL Site (Fort Devens 1991), and has been adopted for application to the Annex. E & E used the procedures described below at the Annex to classify and handle its investigation-derived wastes.

3.1.9.1 Screening Procedures

The screening procedures for the Annex were as follows:

- All material (soils and waters) were screened using an OVA. Any
 materials exceeding background were containerized and further tested
 as described below.
- The OVA instrument was calibrated at least once daily in accordance with operating/calibration instructions.

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OVA readings were performed using the following headspace, field analysis procedures:

- Samples were placed in glass containers and the container mouth was covered with aluminum foil and capped;
- Samples were allowed to stabilize at a temperature of at least 20 degrees Celsius for at least 45 minutes;
- The sample container was then removed, exposing the inner aluminum foil cover. The foil cover was pierced with the OVA probe to measure the total organic vapor concentration in the sample headspace.
- For well and soil borings, the sample was collected from the splitspoon samples obtained for each 5-foot auger flight interval. Auger cuttings were also examined for signs of contamination (i.e., staining or free product).
- For well development and purge water, the water was collected in 55-gallon drums. One sample for OVA evaluation was obtained from each drum.
- For decontamination liquids, at least one sample for OVA evaluation was collected from each drum of the containerization "pad" water prior to any discharge being permitted.

3.1.9.2 Material Handling

Soil and liquids exceeding background were containerized for further testing described below. Soils were consolidated in U.S. Department of Transportation (DOT)approved, 55-gallon drums. Liquids were also consolidated in DOT-approved, 55-gallon drums.

Soils and liquids whose corresponding OVA samples were no more than background were disposed of at the site of generation. Liquids were discharged to the ground so that surface runoff was minimized.

3.1.9.3 Waste Classification Analysis

Wastes generated during the course of field work for the RI investigations were containerized following the procedures noted in the section above. These wastes are currently staged onsite at the Annex and will be classified by the U.S. Army prior to their disposal.

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3.1.9.4 Waste Minimization

The principal goals of waste minimization efforts were to reduce the quantity of wastes generated, to leave wastes on site that do not require off-site disposal, and to remove wastes that do pose a threat to human health or the environment. Investigation methods that minimized the generation of wastes were used where they were feasible and not in conflict with sampling procedures required to avoid cross-contamination. The field teams limited their contact with contaminants and potentially contaminated material during sampling activities whenever possible.

Wastes that were apparently not contaminated were left on site. Soil cuttings were spread around the well location, if no levels above background were recorded after testing the cuttings with an OVA. Purged groundwater was screened with an OVA. If no readings above background levels were recorded, the water was discharged to the ground and allowed to infiltrate. PPE and disposable sampling equipment used during the investigation are being temporarily staged in a secure location on site. Classification and disposal of wastes will be performed at a later date by the U.S. Army.

3.2 ANALYTICAL PROGRAM

3.2.1 Methods, Analytes, and Detection Limits

Chemical analyses for the Annex field investigations were performed at E & E's Analytical Services Center (ASC) in accordance with the E & E Master Quality Assurance Project Plan (MQAPjP) prepared in support of analytical work under contracts for TEPS for the USAEC (E & E 1993). Analyses performed at DataChem Laboratories and Environmental Science and Engineering Laboratories, Inc. (ESE) were performed in accordance with EPA-validated methodologies or the methodologies previously certified for other projects. Specific methods, analytes, and detection limits are listed in Appendix F.

3.2.2 Quality Control Program

3.2.2.1 Field QC Samples

Various types of field QC samples were used to check the effectiveness of field sample-handling methods. They were analyzed in the laboratory as samples, and were used to assess whether or not the sampling and transport procedures were possible sources of sample contamination and to determine overall sampling and analytical precision. The evaluation of field QC results and the potential impact on the data useability are described in Section 3.3.3.

The field QC samples collected for each RI are described in Volumes II and III. A summary of the field QC results is provided in Appendix F. A general description of the type of field QC samples collected is provided below.

 Trip Blanks are field blanks that were not exposed to field conditions. Their analytical results provided the overall level of

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contamination from everything except ambient field conditions. Trip blanks were prepared in the field the day of sampling and shipped with the sample bottles. Trip blanks were prepared by adding organic-free water to a 40-ml VOA vial containing 2 to 3 drops of concentrated hydrochloric acid. One trip blank was used for every 10 VOA samples and shipped with each sample cooler containing the volatile samples. Each trip blank was transported to the sampling location, handled like a sample, and shipped to the laboratory for analysis without being opened in the field.

- Field Equipment/Rinsate Blanks are field blank samples designed to demonstrate that sampling equipment was contaminant-free or cleaned before field use and that cleaning procedures between samples were sufficient to minimize cross-contamination. Rinsate blanks were prepared by passing analyte-free water over sampling equipment and analyzing the samples for all applicable parameters. One rinsate blank sample was collected per 10 samples collected per matrix.
- Field Duplicates consist of a set of two samples collected independently at a sampling location during a single sampling event. Field duplicates assess the consistency of the overall sampling and analytical system. One set of duplicates was collected for every 20 samples of each type of matrix.
- Matrix Spike/Matrix Spike Duplicates (MS/MSD) are actual field samples identified by the field personnel for additional laboratory QC samples as required by the work plan. The QC samples are spiked in the laboratory to determine the potential effects of matrix interferences on sample analytical results. A set of laboratory matrix QC samples was analyzed for each type of matrix for each watershed. Extra sample volume was normally submitted by field personnel, but all other procedures were handled at the laboratory.

3.2.2.2 Laboratory Quality Procedures

Laboratory chemical analyses for the Annex were performed by E & E's ASC in Buffalo, New York; ESE in Gainesville, Florida; and DataChem Laboratories in Salt Lake City, Utah. All analyses were performed in accordance with the requirements of the Quality Assurance Guidelines for Implementation of Environmental Regulation 1110-1-263 for USAEC Projects (USAEC 1993). The program requires approval of the method and reporting limits by the USAEC Chemistry Branch and requires control of the sample analysis and reporting by the grouping of samples into analytical lots.

Laboratory QC procedures are specified by lot for each type of analytical method. OC samples include standard matrix method blanks and standard matrix spikes at levels near

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both the lower and upper reporting limit. Spike recoveries are entered into USAEC-supplied software for the generation of control charts. Control charts are used to monitor the variations in the precision and accuracy of routine analyses and detect trends in these variations. Out-of-control results require immediate re-analysis or a complete justification in the weekly control chart reports submitted to the USAEC Chemistry Branch and the project QA coordinator. All data reported outside control limits were rejected or qualified as described in Section 3.3.3. Calibration procedures and other QC procedures are specified by the method. A summary of the laboratory QC results is provided in Appendix F.

3.3 DATA MANAGEMENT PROGRAM

This section describes the data management program that was implemented to ensure that accurate and complete data were provided for the production of this report and associated electronic deliverables. The discussion below outlines the steps that E & E and the project laboratories followed to ensure the flow and quality of data from input in the field to delivery to USAEC's IRDMIS. The discussion also outlines QA/QC procedures for assessing data useability implemented as part of the analytical data review process.

3.3.1 Database Management

The overall data management program covers three interrelated categories of data, which originate from separate sources:

- · map data,
- geotechnical data, and
- · chemical data.

The acquisition of field data began with a site visit by E & E personnel and a scoping meeting during the project planning phase. The scoping meeting resulted in the definition of site-specific data requirements, which were incorporated into an addendum to the SI/RI Work Plan, SI/RI Field Sampling Plan, and QAPjP. The plans provided initial requirements for sampling locations, site identifications (IDs), chemical tests, and QC sample requirements. These initial requirements were subject to review and approval by USAEC and outside regulatory agencies. Any deviations from the approved plans due to site conditions encountered during the field investigation were tracked using the Sudbury Training Annex Site Master Database maintained in E & E's USAEC Project Management Office in Arlington, Virginia. The Site Master Database includes information on the site IDs, field sample numbers, the planned analytical tests, and QC samples. The Site Master Database served as the mechanism for ensuring that samples were collected as specified in the SI/RI Work Plan, Field Sampling Plan, and QAPjP.

Map data for the field investigations were assembled prior to the start of field operations. Each map entry, or record, contains information for one sampling point at the Annex, including the site ID, description, relation to other sites in the map file, site elevation

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in feet AMSL, and horizontal location of the site based on the Massachusetts State Planar (STP) coordinate system. Site elevation and location were estimated for creation of the map records at first, and then updated with actual data (frequently from a licensed surveyor) after completion of field work. The map file for the Annex currently contains approximately 2,200 data items that define a variety of sample points, well locations, ground contours, etc. The map file was created prior to the start of field work because map records must be in the IRDMIS database before it will accept other data, either geotechnical or analytical.

Geotechnical data were submitted to IRDMIS: during the course of field investigative work. Three categories of geotechnical data were recorded and delivered to IRDMIS: field drilling data, monitoring well construction data, and groundwater elevation data. Field drilling data were logged by E & E geologists during the monitoring well installation and soil boring programs, and consist of descriptions of the lithology encountered during drilling. Monitoring well construction data consisted of the physical measurements of well construction, including the depths at which the well's sandpack, screen, and grout components were installed. Groundwater elevation data were recorded during discrete rounds of groundwater level measurements and were submitted to IRDMIS after the completion of the round.

E & E entered the map and geotechnical data from the standardized form into a microcomputer, using the PC Data Entry and Validation Subsystem Software IRDMIS PC Tool (Potomac Research Inc. (PRI) 1991), and transmitted to the USAEC IRDMIS system by uploading these files over the 3COM network to the central computer.

For the chemical data, an electronic site ID file from the Site Master Database was sent to the laboratories prior to the field event. The laboratories generated preprinted labels with the appropriate IDs, analytical parameter, and preservation. E & E field personnel completed chain-of-custody (COC) records, including field information, for the laboratory to enter into IRDMIS. At the laboratory the samples were logged into the laboratory management system by comparing them to the site ID file and assigned to individual lots (i.e., analytical batches) for each chemical test. The laboratory then produced sample received reports, lot status reports, and draft data summary tables for review by the project QA chemist at various stages prior to submitting the data to IRDMIS. Discrepancies in the site IDs and assigned chemical tests between the Site Master Database, field COCs, and the laboratory were resolved by the project QA chemist, laboratory data manager, and project manager. After analysis was performed and the lot was determined to be acceptable (see Section 3.3.3), the laboratory entered raw laboratory analytical results using the IRDMIS PC Tool software and produced a transfer file. These data were subsequently group checked, submitted to the project QA chemist for approval, and then uploaded to the central USAEC computer over the 3COM network.

IRDMIS performed validation checks on the quality of these data and noted any exceptions (errors). Data for which exceptions were noted could not be made available for further processing (i.e., elevated to Level III) until the errors were corrected. Weekly error reports were provided to the E & E Project Manager by USAEC. The project QA chemist, E & E data manager, and the laboratory data manager were responsible for ensuring that the

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corrections were made. In some cases this required consultation with the USAEC chemist prior to approval of the data lot for acceptance at Level III IRDMIS. Once all the data for the event were processed, the IRDMIS results were downloaded into the Site Master Database for data reduction and reporting.

3.3.2 Data Reduction and Reporting

Analytical data were downloaded from IRDMIS when all data for a sample event were processed and any group or record check errors were corrected. The data were transferred to the Site Master Database, a specialized software program E & E developed in dBase III[®], a relational database management system, and Clipper[®] (a compiler for dBase) to implement data reduction operations using E & E's in-house microcomputers.

Chemical data files were divided into two types of data files, field sample data and QC data. The field sample data file contained all required chemical tests for each sample as submitted by the laboratory. The QC data file contained field QC samples (i.e., rinsates, trip blanks, and duplicates); field and laboratory QC samples (i.e., MS/MSD); and laboratory-specific QC samples (i.e., method blanks, standard matrix spikes, and sample surrogate recoveries). Two types of reports were generated, each by site type, watershed, and by sample media: a "hits only" data summary table, and an "all data" table. The "hits only" data summary table provides summarized results for any compound detected in that sample media at each watershed. An "all data" table contains all the results for all parameters analysis for all samples. The tables were initially generated in format for review by the project QA chemists and for addition of any data useability codes, as described in Section 3.3.3. During the initial review the QA chemists also verified that the data were complete and compared them to the sampling requirements specified in the Work Plan, Field Sampling Plan, and QAPjP.

Following review and entry of data useability codes, the tables generated for the report writers and the electronic files were transferred to risk assessors and the computer-aided design (CAD) group for further processing. Because the "all data" table is extensive, it is placed in Appendix M in the form of a diskette. The data summary tables were initially screened for data determined to be useable during the QA review (see Section 3.3.3). The data were then compared against background values or ARARs as described in Section 7. The results above background or ARARs were highlighted and discussed in the Nature and Extent of Contamination for each watershed. Results were also formatted as charts to demonstrate contaminant distribution as appropriate.

3.3.3 Analytical Data Review

Analyses of the Annex samples were performed by E & E's ASC, ESE, and DataChem. Analyses included TCL VOCs, BNAs, Pest/PCBs, TAL Metals, explosives, TOC, TPHC, anions, herbicides, organophosphorus pesticides, and percent solids. A summary of the methods for each laboratory is provided in Appendix F. Analytical data were reviewed at three levels by the laboratory, USAEC Chemistry Branch, and the project QA coordinator.

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At the laboratory level, analytical data were first evaluated by comparing standard matrix spike recoveries to method-specific control limits. The evaluation was submitted in weekly control chart summaries to the USAEC Chemistry Branch for approval and to a project QA chemist for review. The USAEC Chemistry Branch reviewed all method control charts and determined acceptability for submission to IRDMIS. The laboratory also notified the project QA chemist if any results might be rejected because they were outside control limits, and when re-analysis would be beyond holding times. When possible, these samples were recollected for the specific analysis if approved by the project manager and USAEC contracting officer's representative. Any other results were qualified as described below.

As a standard of practice, the laboratory assigns a flagging code to designate spike recoveries outside limits, results outside the method linear range, compounds also detected in the method blank, and other analytical concerns. The USAEC Chemistry Branch assigns a data qualifier in IRDMIS based on their review of the control chart submission. It is then the responsibility of the project QA chemists to review both the flagging codes and data qualifiers along with the field quality control results, and to assign a single code indicating data useability. Data useability codes appear on the data summary tables and are described as follows:

- "B" Sample result is less than five times the result in the
 associated method blank, rinsate, or trip blank and should be
 considered not site-related but attributable to background
 contamination. For common laboratory contaminants, the result is
 flagged if it is less than 10 times the method blank.
- "J" Sample result is estimated due to calibration or QC problems, but usable for evaluating site-related contamination. The estimated flag is also used if results are reported below the method detection limit but above the instrument detection limit.
- "K" Sample result is biased high due to interference, background contamination, or high spike recovery, but useable for evaluating site-related contamination.
- "L" Sample result is biased low due to low spike recovery, but useable for evaluating site-related contamination.
- "R" Sample result is rejected and data are not useable for evaluating site-related contamination.
- "U" Sample result is not confirmed on a second column and, therefore, the compound is not present.
- "C" Sample result is confirmed on a second column and, therefore, the compound is likely to be present.

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Any result qualified with a "B", "U", or "R" was not used for evaluating site-related contamination. Any result with a "J", "K", and "L" was used for evaluating site-related contamination, but any comparison of the values to ARARs was considered questionable.

As discussed in Section 3.2.2.1, several types of field QC samples were taken throughout the investigation. The QC sample results were reviewed and used to qualify analytical data presented for each site as described above. All field QC sample results are presented in Appendix F and discussed briefly below.

Field duplicates were taken for each site to assess overall sampling and analytical precision for various matrices. For each duplicate pair, a RPD was calculated for all detected compounds and presented on summary tables in Appendix F. In general, duplicates with high RPDs outside of the EPA Region I criteria of 30 percent for waters and 50 percent for soils indicate non-homogeneous sample matrices, or poor sampling or analytical precision. As a result, related sample data are qualified as estimated.

Field blank rinsates were collected throughout the investigation at various sites. The results for all detected compounds are summarized in Appendix F. The rinsates for groundwater were collected from disposable bailers and analyzed for all parameters of concern at that site to evaluate potential residual contamination. Rinsates for groundwater were also collected from the filtering apparatus and analyzed for TAL metals to evaluate potential cross-contamination permitted despite decontamination procedures. The rinsate results are directly comparable to groundwater sample results, and any sample results less than five times the blank level was attributed to blank contamination. No rinsates were collected for surface water samples, since no sampling equipment is used in their collection other than the sample bottles themselves. For soils and sediments, rinsates were collected from split-spoon augers and disposable aluminum pie tins used to composite samples. These rinsate results were converted to units of $\mu g/g$, using the final sample volume and the amount of soil used in the comparable soil method, and the sample results were qualified if they were less than five times the converted rinsate values.

Trip blanks were sent with sample shipments throughout the investigation and analyzed for VOCs to assess potential contamination during transport. Generally, all the VOC samples for the day were combined in a single cooler and shipped with a trip blank. The results for detected compounds only are summarized in Appendix F. If the sample result was less than five times the trip blank levels for the day it was shipped, the sample result was qualified.

Samples were also collected for explosive compounds, pesticides/PCBs, and inorganics MS/MSD analysis. These samples were designated by field personnel as representative matrices for each site. The MS/MSD results are summarized in Appendix F. Both percent recoveries and RPDs were calculated and compared to EPA Region I criteria for the CLP. If the lot QC spike samples were within control limits, but the MS/MSD results were outside limits, matrix interferences were suspected and the sample results were qualified as estimated.

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In addition to the chemical data file, the laboratory produces a hard copy data package with all calibration information, raw data, and a case narrative describing any problems. All data packages were reviewed by the laboratory QA coordinator. Approximately 10 percent of the packages were reviewed by project QA chemists to ensure that USAEC requirements specified in the QAPjP were followed. The review focused on data packages containing data that exhibited suspect results due to apparent values outside of acceptable limits. For TCL organics and TAL metals, additional lot packages were reviewed to evaluate how the data compare to EPA CLP requirements. All the results were comparable and no effect on data useability was determined.

3.4 HEALTH AND SAFETY PLAN FIELD PROCEDURES

3.4.1 Health and Safety Plan

The Health and Safety Plan Addendum (HASP), (E & E 1994e), developed for field activities at the Annex was designed to ensure that E & E and subcontractor personnel comply with all applicable Federal, State, and local safety and health regulations. The HASP describes specific responsibilities, training requirements, medical and environmental surveillance, hazard communication, protective and emergency equipment, environmental monitoring, and safe operating procedures to be followed at each site.

The Corporate Health and Safety Officer (CHSO) at E & E is responsible to the Program Manager for the overall development of the HASP, based on an analysis of activities planned at the site. The Health and Safety Advisory Committee serves to coordinate the medical and exposure monitoring of field personnel. The Project Manager for the Task Order coordinates implementation of and accessibility to the HASP. The Site Manager and Field Safety Coordinators are responsible for implementing the HASP in the field, and all field personnel (E & E and subcontractor) are required to review and comply with the HASP.

3.4.2 Health and Safety Plan Field Procedures

Prior to any field activities, all field personnel are trained in health and safety requirements. Specialized training is provided, as mandated by site conditions or by activities anticipated during the field work. Site personnel are not authorized for field work unless all health and safety base requirements are met. A Health and Safety Plan containing specific information pertinent to the site is developed for each site. If the plan needs to be amended, a "Site Safety Plan Addendum Form" is completed and submitted to the CHSO for approval. All personnel are required to follow the HASP.

Daily health and safety briefings are conducted prior to field entry to ensure that any concerns related to planned activities are covered and are understood by all team members. Sign-off sheets document attendance and discussions. In addition, teams are required to keep daily logs of all field activities performed, including the daily briefings, other ad hoc briefings, significant events, or noteworthy changes in field conditions. The site log is the responsibility of each team leader and is meant to provide a defensible record of the day's activities and field conditions. Past investigation briefings are held after field work is

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completed in order to review site activities and field conditions and any changes expected for either in subsequent efforts.

Two types of field equipment are available for use as required. PPE is selected based on an analysis of site conditions and planned activities. Requirements can be revised by the Field Safety Coordinator on an "as needed" basis to meet changing site conditions. Level D was used for the RI site work. Environmental monitoring equipment is issued for personnel safety monitoring and is selected to monitor for possible site emergencies or unexpected conditions. Emergency equipment is provided to meet site emergencies.

Communication equipment was provided to field personnel, and information on emergency procedures and the available emergency services was provided to all field teams. It was ascertained that all personnel understood how to respond to an emergency and the correct procedures for reporting an incident or an accident.

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4. HUMAN HEALTH RISK ASSESSMENT APPROACH

4.1 INTRODUCTION

This section describes the general approach used in the human health risk assessments for the two RI areas within the Annex: P11/P13 and P36/P37/A12. The risk assessments for the individual sites are presented in Volumes II and III.

4.1.1 Overview

Since the early 1940s, the Sudbury Annex has had many uses including ammunition storage, ordnance research and development, laboratory research, field testing of equipment, training of Army troops and others, and possibly waste disposal. Several areas of the Annex have apparently been contaminated as the result of past site activities. Risk assessments have been prepared in conjunction with the RIs for two areas: Site P11/P13, which is located within the northern section of the Annex and Site P36/P37/A12, which is located on the southern section. Both of these sites are currently inactive. Site P11/P13 was used by the Army for various research and laboratory activities and later by the MFFA for training; metal and pesticide contamination has been detected in site soil, sediment, surface water, and groundwater. Site P36/P37/A12 was once a research and development facility and was later used for transformer storage. Elevated concentrations of metals, PCBs, and pesticides have been detected in site soil, sediment, and groundwater.

A few areas of the Annex are still active. The southern section contains the CFHA, the only residential area on the Annex, and an area for testing cloth durability (part of Site P48). The northern section of the Annex contains a USAF radar installation on the western portion, a drop zone near the center that is used for aerial testing done with remote control aircraft, the FEMA regional operations center near the east boundary, and old ordnance bunkers in the eastern portion that are now used by the Army and various leaseholders for equipment and chemical storage. Until recently, the northern section was also used on a regular basis for Army reserve and active duty training activities as well as occasional training exercises conducted by State Police and National Guard units. The Annex was formally closed to training on 30 September 1992, however, training may still be permitted under exceptional circumstances (USAEC 1992). The Army permits local residents to enter the Annex for recreational activities such as fishing at Puffer Pond or model airplane flights at the air drop zone.

The Annex is surrounded by four towns, Sudbury to the southeast, Hudson to the southwest, Stow to the northwest, and Maynard to the northeast. Most of the Annex and several areas within the Annex are enclosed by chain-link fence, and barriers have been placed across roads to prevent vehicle entry. Access is further restricted by controlling entry at the main gate and periodically patrolling the roads. These measures limit, but do not

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entirely prevent, unauthorized entry. Trespassing commonly occurs around road barriers and through gaps in the perimeter fence.

4.1.2 Conceptual Site Model

A conceptual site model for the two RI areas in the Annex is presented in Figure 4-1. Soils in both areas were contaminated as a result of past site activities and storage practices. Contaminants may have migrated with surface runoff into adjacent streams, and, if soluble, may have leached to groundwater which also discharges into the streams.

Under current site conditions, potential pathways for human exposure to site-related contamination include:

- Direct contact (dermal contact and incidental ingestion via hand-tomouth contact) with contaminated surface soils at the sites; and
- Direct contact with sediment and surface water in streams, downgradient from the sites.

Both sites are currently inactive; therefore, the only receptors are site visitors, who are most likely to be trespassers from nearby residential areas. Inhalation of contaminated dust is not regarded as a major exposure pathway because wind erosion of soil is limited by pavement, structures, and vegetative cover. Volatile chemicals were detected only infrequently and at trace concentrations in site soils, therefore, vapor emissions from soils are also considered to be negligible. Groundwater is not currently used at either of the sites; therefore, direct contact with groundwater contamination cannot occur under existing site conditions.

The Annex sites could be excessed or sold in the future. Areas that have already been excessed are used recreationally; however, conversion of excessed areas to residential use is also possible. Future site residents could be exposed to site-related contaminants by the same pathways as current site visitors. If site soils were excavated for future home construction, bringing subsurface soils to the surface, construction workers and future residents could potentially be exposed to both surface and subsurface soil contaminants. Direct use of site groundwater by future residents is unlikely because of the availability of public water supplies; however, if future residents were to install private wells, they could also be exposed to groundwater contamination through domestic water usage.

4.1.3 Organization of the Human Health Risk Assessments

The risk assessments have been prepared in accordance with EPA's Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (RAGS-HHEM) (USEPA 1989), and with other related EPA guidelines listed in the work plan. This risk assessment approach section describes the general approach used in the site-specific risk assessment sections (presented in later volumes) and includes the information that is common to both of the sites covered by this RI report. This section is organized as follows:

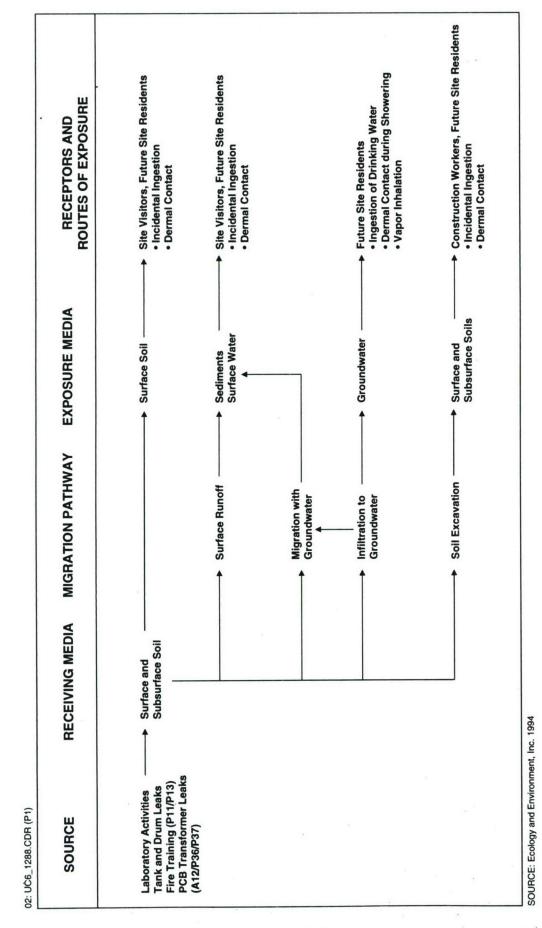


Figure 4-1 CONCEPTUAL SITE MODEL FOR THE SUDBURY ANNEX RI SITES

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• Section 4.2 briefly reviews the site characterization data available including the sampling plan, sampling and analytical methods, and

- data limitations, and describes the process and the criteria used to select contaminants of potential concern (COPCs) at each site,
- Section 4.3 provides toxicity assessments for the COPCs at all of the sites. Toxicity assessment methodologies are reviewed and a brief discussion of the toxicological properties of each chemical is provided, along with tables summarizing the quantitative indices of toxicity that were used to estimate the magnitude of risks,
- Section 4.4 reviews all of the potentially complete exposure pathways and generally describes how exposure estimates were derived for the site-specific risk assessments,
- Section 4.5 describes how the toxicity and exposure estimates are combined to quantitatively estimate potential risks posed by site COPCs and explains how these risk estimates are compared to risks considered acceptable by EPA, and
- Section 4.6 discusses the sources and magnitudes of uncertainties in the risk assessment process that affect the precision and accuracy of the resulting risk estimates.

4.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN (COPCs)

4.2.1 Data Collection

The objective of the RIs at the Annex was to characterize the nature and extent of contamination associated with the sites and to assess the site topography, geology, hydrogeology, climate, and land uses in order to identify and evaluate potential migration and exposure pathways. The investigative activities carried out to achieve this objective are described generally in Section 3 of this volume. Details of sampling conducted and the results of the RI for each site are described in Sections 2 through 5 of the site-specific RI reports.

The RI data were supplemented in some cases with data from previous SIs to provide more complete characterization of contamination at the sites. See the site-specific risk assessments (Section 6 in Volumes II and III) for details.

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4.2.2 Data Evaluation

4.2.2.1 Data Validation

Analysis of samples for the RIs was performed by E & E using USAEC-approved methods. E & E reviewed and validated the data as described in Section 3.3. Only data determined to be useable for assessing site-related contamination were used in the risk assessment.

The RI data for site P11/P13 was supplemented with soil and groundwater data from the previous site investigation conducted by OHM (OHM 1994). Sample analyses were performed by two laboratories, Environmental Testing and Certification Corp. (ETC) of Edison, New Jersey; and PACE Incorporated (PACE) of Minneapolis, Minnesota using USAEC-approved methods. ETC performed analyses for TCL VOCs, TCL BNAs (semivolatile organics), and TAL metals. PACE performed pesticide/PCB analyses. Data review and validation are described in Section 3.19 of OHM's SI Report (OHM 1994).

4.2.2.2 Quantitation Limits

The quantitation limits used in the analytical work were the certified reporting limits (CRLs) for the USAEC methods, employed by ETC and PACE, and the approved method reporting limits (MRLs) for USAEC methods, employed by E & E. In accordance with EPA risk assessment guidance recommendations (USEPA 1989), the adequacy of the quantitation limits for soil and water were evaluated by comparing them with estimated risk-based chemical concentrations. The risk-based concentrations (RBCs), which were calculated using standard default exposure assumptions for residential soil and water ingestion, correspond to a cancer risk of 10⁻⁶ for carcinogens, or a hazard index of 1 for noncarcinogens. Intake rates were assumed to be 100 milligrams (mg) of soil per day or 2 liters of drinking water per day for a 70-kilogram (kg) adult, 350 days per year over a 30-year period.

Table 4-1 presents the quantitation limits used for chemicals detected at the two sites. The quantitation limit is the lowest level at which the chemical can be accurately and reproducibly quantitated. The quantitation limits shown apply to most, but not all, of the samples analyzed. Some samples had elevated quantitation limits, above those listed in Table 4-1, due to sample-specific adjustments, such as dilution of the sample because of a high concentration of another chemical in the sample. Elevated quantitation limits are discussed further below. Quantitation limits in the table that exceed risk-based concentrations have been flagged.

The soil quantitation limits of all chemicals, except for beryllium and carcinogenic PAHs, are lower than their risk-based concentrations, indicating that they are adequate for risk assessment purposes. E & E's quantitation limits for beryllium and carcinogenic PAHs exceed their respective cancer RBCs by small amounts (less than two to five times the risk-based value). These quantitation limits would not be entirely adequate for assessing risks under a residential land-use scenario because contaminant concentrations approaching these levels might not be detected, yet could potentially pose significant risks to residents exposed on a daily basis for an extended period. Current exposures are less frequent than daily

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APROVIACY	NE OUAL TOTAL		Table 4					
ADEQUACY O	F QUANTITAT		oil	EMICALS I	DETECTED		JRY ANNEX	× .
				Based rations ^a			Risk-I Concentr	
Chemical	E & E CRL (mg/kg)	OHM ^f CRL (mg/kg)	Cancer Risk of 10 ⁻⁶ (mg/kg)	Hazard Index of 1 (mg/kg)	E & E CRL (μg/L)	OHM ^f CRL (µg/L)	Cancer Risk of 10 ⁻⁶ (µg/L)	Hazard Index of 1 (µg/L)
Metals								
Aluminum	300	17.2	-	-	25.0	172	_	-
Antimony	0.500	1.98	-	290	5.00	30.9 ^d	_	1
Arsenic	0.200	0.496	0.95	220	2.00°	2.5°	0.047	1
Barium	5.00	9.11	-	51,000	10.0	111	_	2,60
Beryllium	0.500 ^c	0.212	0.40	3,600	5.00°	2.09 ^c	0.020	18
Cadmium	0.500	0.328	-	730	5.00	3.26	_	1
Calcium	500	313	_	_	500	2,080	_	_
Chromiume	2.0	3.25	_	3,600	10.0	5.49	_	18
Cobalt	1.00	2.05	_	_	10.0	24.1	_	_
Copper	1.00	2.13	-	27,000	10.0	7.1	_	1,40
Iron	350	9.42	-	_	25.0	94.2	_	
Lead	0.500	0.300	-	1,800	5.00	1.5	_	2
Magnesium	500	183	_	_	500	1,990	_	_
Manganese	6.00	0.886	-	100,000	5.00	4.89	_	186
Mercury	0.100	0.059	-	220	0.200	0.169	_	1
Nickel	1.00	0.987	-	15,000	10.0	30.1	-	73
Potassium	200	165	-	_	1,000	1,920	-	_
Selenium	0.200	0.581	-	3,600	2.00	3.31	_	180
Silver	0.200	0.745	_	3,600	2.00	6.59	-	180
Sodium	200	264	-	-	2,000	2,680	_	_
Thallium	0.500	0.394	-	51	2.0 ^d	3.78 ^d	_	1.7
Vanadium	2.00	1.84	_	5,100	10.0	24.1	_	260
Zinc	2.00	7	-	220,000	20.0	8.93	_	11,00
Pesticides/PCBs			-					
α-Chlordane	0.002	0.004	4.4	146	0.100 ^c	0.02	0.066	2.2
γ-Chlordane	0.008	0.021	4.4	146	0.100 ^c	0.045	0.066	2.2
p,p'-DDD	0.002	0.011	24	-	0.040	0.085	0.35	_
p,p'-DDE	0.002	0.014	17	-	0.040	0.095	0.25	
p,p'-DDT	0.002	0.01	17	1,200	0.040	0.032	0.25	18
Dieldrin	0.002	0.008	0.11	36	0.040 ^c	0.032 ^c	0.0053	1.8
α-Endosulfan	0.001	0.005	-	4,400	0.020	0.009	-	220
β-Endosulfan	0.002	0.007		4,200	0.020	0.012	-	220
Endrin	0.002	0.011	_	220	0.040	0.037	-	11
Heptachlor	0.001	0.01	1.3	1,200	0.020 ^c	0.063 ^c	0.019	18

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			Table 4-	1				
ADEQUACY OF Q	UANTITAT			EMICALS I	DETECTED	AT SUDBU	RY ANNEX	<u> </u>
		S	Soil		L	Wa	ter	
w			Risk-l Concent				Risk-I Concentr	
Chemical	E & E CRL (mg/kg)	OHM ^f CRL (mg/kg)	Cancer Risk of 10 ⁻⁶ (mg/kg)	Hazard Index of 1 (mg/kg)	E & E CRL (μg/L)	OHM ^f CRL (µg/L)	Cancer Risk of 10 ⁻⁶ (µg/L)	Hazard Index of 1 (µg/L)
Heptachlor epoxide	0.001	0.004	0.19	9.5	0.020 ^c	0.006	0.0094	0.48
α-Benzene hexachloride	0.001	0.003	0.27	-	0.020 ^c	0.043 ^c	0.014	_
β-Benzene hexachloride	0.001	0.005	0.94	_	0.020	0.011	0.047	_
δ-Benzene hexachloride	0.001	0.023	-	-	0.020	0.049	_	-
Methoxychlor	0.008	0.211	-	12,000	0.20	0.267	-	180
PCB 1254	0.020	0.04	0.74	12	0.500 ^{c,d}	0.10 ^c	0.011	0.18
PCB 1260	0.020	0.04	0.74	12	0.500 ^{c,d}	0.10 ^c	0.011	0.18
Semivolatile Organics				•		•		
Acenaphthene	0.330	0.036	-	44,000	10.0	1.70	-	2,200
Benzo(b)fluoranthene	0.330 ^c	0.210	0.23	29,000	10.0°	5.40 ^c	0.012	1,500
Bis(2-ethylhexyl)phthalate	0.330	0.250	120	15,000	10.0 ^c	6.50	6.1	730
Butylbenzylphthalate	0.330	0.066	-	150,000	10.0	0.870 ^c	-	7,300
Chrysene	0.330 ^c	0.120	0.23	29,000	10.0 ^c	2.40 ^c	0.012	1,500
Di-n-butylphthalate	0.330		_	73,000	10.0		_	3,650
Di-n-octylphthalate	0.330		-	15,000	10.0		-	730
Fluoranthene	0.330	0.068	-	29,000	10.0	3.30	-	1,500
2-Methylnaphthalene	0.330	0.1	-	29,000	10.0	3.4	-	1,500
Phenanthrene	0.330	0.083	_	29,000	10.0	2.5	_	1,500
Pyrene	0.330	0.27	_	22,000	10.0	6.2	-	1,100
Volatile Organics								
Acetone	0.100	0.013	-	73,000	10.0	6.6		3,650
2-Butanone (Methyl ethyl ketone)	0.010	0.004	-	440,000	10.0	7.8	-	22,000
Methylene chloride	0.005	0.006	230	44,000	5.00	5.3	. 11	2,200
Toluene	0.005	0.002	_	146,000	5.00	1.2	-	7,300
1,1,1-Trichloroethane	0.005	0.001	-	66,000	5.00	4.3	_	3,300

a Calculated for a 70-kg adult resident who ingests 100 mg of contaminated soil per day for 350 days per year for 30 years.

0.005

Source: Ecology and Environment, Inc., 1994.

220,000

5.00

Trichlorofluoromethane

11,000

b Calculated for a 70-kg adult resident who ingests 2 L of contaminated water per day for 350 days per year for 30 years.

CRL exceeds concentration associated with a cancer risk of 10⁻⁶.

d CRL exceeds concentration associated with a hazard index of 1.

Risk-based concentrations for chromium are based on chromium (VI), the more toxic of the two forms found in the environment.

Metals, semivolatile organics, and volatile organics were analyzed by ETC. Pesticides/PCBs were analyzed by PACE.

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(probably less than 100 days per year for any individual). Therefore, the soil CRLs for beryllium and PAHs also appear to be adequate for assessing risks for current exposures.

Quantitation limits for semivolatile organic chemicals were elevated above the CRL values in a number of soil and sediment samples, as follows: 10 times OHM's CRLs in six of the 15 surface soil samples from Site P11/P13; 6 times E & E's CRLs in three of eight sediment samples from Site P11/P13; and 6 to 9 times E & E's CRLs in three of 18 surface soil samples from Site A12/P36/P37. The elevated detection limits for carcinogenic PAHs, which exceed the RBCs by approximately an order of magnitude, are not entirely adequate for assessing future residential risks but may be adequate for assessing current risks to site visitors. Pesticide/PCB quantitation limits were also elevated in some soil and sediment samples, as follows: 4 to 20 times E & E's CRL in five of 31 surface soil samples from both sites; 2 to 4 times the CRL in the nine subsurface soil samples from Site A12/P36/P37; and 2 to 25 times the CRL in 12 sediment samples in both areas. The elevated quantitation limits for pesticides and PCBs in soils and sediments do not exceed RBCs and are, therefore, considered to be adequate.

The water CRLs for a number of chemicals, mainly carcinogens, exceed their RBCs (see Table 4-1). This indicates that the quantitation limits for these chemicals would not be entirely adequate for evaluating water used directly as a residential water supply source, because significant risks could exist but be overlooked if these chemicals were present in drinking water at concentrations below but approaching their quantitation limits. The chemicals of most concern with respect to inadequate water quantitation limits are carcinogenic PAHs, beryllium, arsenic, and PCBs.

Quantitation limits for pesticides and PCBs were several times higher than E & E's CRLs in a few surface water and groundwater samples from Site P11/P13, as follows: approximately 5 times CRLs in one surface water sample, and 4 times CRLs in three groundwater samples. For heptachlor and β -benzenehexachloride, whose CRLs were at or near their respective RBCs, the elevated quantitation limits in water may not be entirely adequate for risks from drinking water.

4.2.2.3 Data Qualifiers and Data Useability

The USAEC/IRDMIS analytical methodologies and data system use a somewhat different set of data qualifiers than EPA's CLP. The useability of the data for risk assessment purposes was determined using established EPA guidelines (USEPA 1992a). A number of samples fell outside of normal QC limits for reasons such as exceeded holding times and low spike recoveries. Some of the values are described as "estimated" or biased because of these discrepancies. Guidance on data useability for risk assessment recommends that estimated values be included in the risk assessment because, even though these data may not be as reliable as data meeting all QA criteria, they still represent the best available estimate of the analyte's concentration in that sample. Therefore, as long as a sample result was retained after the QA/QC review, it was included in the database for the risk assessment.

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A few chemicals that were detected in site samples were also detected in the associated blanks. In accordance with EPA guidance, contaminant concentrations in site samples were considered legitimate only if the sample value was at least five times the blank value (10 times for common laboratory contaminants). Results less than 5 or 10 times the blank value were flagged "B" and were not used in the risk assessment. Most of the detections of acetone and methylene chloride were discounted, based on their detection in the associated blanks.

Less than (<) or not detected (ND) notations were attached to the reported values if the chemical was not found in a sample at the specific value. When these results were used to calculate average exposure point concentrations for the quantitative risk assessment in conjunction with a positive value, a value equal to one-half of the reported < or ND value was substituted, unless that value exceeded the maximum detected concentration used in the calculation. If one-half of the < or ND value limit was greater than the maximum detected concentration, the nondetect result was omitted from the calculation.

4.2.3 Selection of COPCs—General Approach and Selection Criteria

Because many metals are naturally present in water, soils, and sediments, it is necessary to distinguish naturally occurring concentrations from those that may be due to contamination when evaluating metals data for risk assessment purposes. Additionally, because pesticides were widely applied in the past for pest control at the Annex and at the areas surrounding the Annex, there are residual levels of pesticides that are unrelated to releases from the RI sites. Background concentrations in soil, sediment, and surface water were derived from data on local background samples collected from locations on or near the Annex in September 1993, outside the areas of contamination. Determination of local background levels is described in Section 6 and Appendix J. Ten soil background samples were collected from locations outside the Annex boundaries that are thought to be representative of regional soil conditions.

Background stream sediment and surface water samples were collected from two locations, one from the outlet of Cutting Pond outside the Annex and one from a tributary to Taylor Brook upgradient from identified areas of activity. Because the background sediment samples have low organic carbon content, they may under represent the actual background concentration ranges for sediments with higher organic carbon content. The stream sediment background values are extremely conservative estimates of local sediment background levels.

Metals and pesticides that were detected in site samples at concentrations exceeding the screening levels were regarded as potentially due to site contamination and were selected as COPCs for the risk assessment. Most other chemicals that were positively detected (not discounted for reasons explained earlier) were selected as COPCs for the human health risk assessment. The few exceptions were chemicals with relatively low toxicities that were detected only once or twice and at low concentrations, typically near detection limits, that would be unlikely to contribute significantly to the risks posed by the sites. These exceptions are discussed in Section 6.2 of the site-specific reports.

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A similar background data set was not used for screening metals detected in groundwater because of the wide variability in groundwater quality and the difficulty of selecting background groundwater locations appropriate for all areas of concern. Instead, the maximum concentrations detected in the upgradient well at each site were used as screening levels for the other wells at the site. Data for filtered groundwater were summarized and screened separately from unfiltered groundwater data; however, as directed by EPA Region I. COPC selection was based on the unfiltered groundwater data.

Many of the unfiltered groundwater samples collected from monitoring wells apparently contained substantial amounts of suspended sediment. Because sediments are composed of soil minerals that contain a variety of metals, groundwater samples containing significant amounts of suspended sediment may exhibit artificially elevated concentrations of many metals. Comparisons of unfiltered and filtered groundwater data from the same wells confirm that a substantial portion of the high concentrations of metals in unfiltered samples (concentrations that result in their selection as COPCs) are not dissolved in the groundwater, but are associated with suspended sediment.

4.3 TOXICITY ASSESSMENT

4.3.1 Introduction

The purpose of the toxicity assessment is to compile toxicity data for the COPCs at either of the sites, and to provide an estimate of the relationship between the extent of exposure to a contaminant and the likelihood and/or severity of adverse effects. The toxicity assessment will be accomplished in two steps: hazard identification and dose-response assessment.

Hazard identification is a qualitative description of the potential toxic properties of the COPCs at the site. Brief health effects summaries for the COPCs are presented below in Section 4.3.2.

The dose response evaluation is a process that results in a quantitative estimate or index of toxicity for each COPC at the site. For carcinogens, the index is the slope factor (SF) and for noncarcinogens, it is the reference dose (RfD). Practices and procedures used to develop quantitative indices of toxicity and to incorporate toxicological information into the risk estimation process and the quantitative indices of toxicity are presented in Section 4.3.3. Uncertainties in the toxicity assessment process are discussed in Section 4.6.1.5.

4.3.2 Health Effects Summaries

The health effects summaries describe the potential toxic properties of most of the COPCs at the Sudbury Annex RI sites. For carcinogens, the weight-of-evidence category is also included. Table 4-2 summarizes the five EPA weight-of-evidence categories. According to these EPA guidelines, chemicals in the first two groups—A and B (B1 or B2)—are considered human carcinogens or probable human carcinogens based on sufficient evidence and should be the subject of nonthreshold carcinogenic risk estimation procedures. Depending

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Table 4-2 **EPA WEIGHT-OF-EVIDENCE** CATEGORIES FOR CHEMICAL CARCINOGENICITY Group Description A Human Carcinogen - sufficient evidence from epidemiological studies to support a causal association between exposure and cancer. **B**1 Probable human carcinogen based on at least limited evidence of carcinogenicity to humans from epidemiological studies; B2 Probable human carcinogen based on a combination of sufficient evidence of carcinogenicity in animals and inadequate evidence of carcinogenicity in humans. C Possible Human Carcinogen - limited evidence of carcinogenicity in animals in the absence of human data. D Not Classified - inadequate evidence of carcinogenicity in animals. E No Evidence of Carcinogenicity for Humans - no evidence of carcinogenicity in at least two adequate animal tests in different species or in both epidemiological and animal studies.

Source: USEPA 1986c.

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upon the quality of the data, Group C chemicals may also be subjected to these procedures. The remaining chemicals—in Groups D and E—are defined as noncarcinogens and should be subjected to threshold-based toxicological risk estimation procedures.

In most cases, the information in the health effects summaries is drawn from toxicity summaries prepared by the USAEC, formerly the United States Army Toxic and Hazardous Materials Agency (USATHAMA 1992) or the Public Health Statement in the Agency for Toxic Substances and Disease Registry's (ATSDR's) toxicological profile for the chemical (ATSDR 1989-1993).

Aliphatic Petroleum Hydrocarbons (Alkanes: C-8 to C-13)

Aliphatic PHC is a term used to refer to a mixture of long-chain hydrocarbon compounds derived from petroleum and which are often components of petroleum products. In general, aliphatic PHCs are regarded as having a low potential for toxicity and there is no evidence that aliphatic PHCs are mutagenic or carcinogenic. Aliphatic PHCs with five or more carbons produce narcosis and central nervous system disturbances and can irritate the lungs at high airborne concentrations. The straight-chain aliphatic PHCs appear to be more toxic than their branched chain isomers. The most toxic aliphatic is n-hexane.

Ingestion or inhalation of n-hexane may cause nausea, vertigo, bronchial and general intestinal irritation, and central nervous system effects. Unconsciousness can result from central nervous system depression. After exposure to 800 ppm for 15 minutes, n-hexane has been shown to irritate the eyes and mucous membranes and skin contact can cause irritation and dryness. Chronic exposure to n-hexane vapors may result in damage to the peripheral nervous system, and symptoms such as numbness to the fingers and toes. If exposure continues, paralysis characterized by impaired walking and grasping may result. Concentrations of n-hexane associated with nerve damage have not been firmly established but symptoms have been observed in humans exposed to concentrations ranging from 10 to 200 ppm for 9 to 12 months.

Aluminum

Aluminum is a naturally occurring, silver-white, flexible metal that is always found in the earth in combination with other elements. By itself, aluminum is used in cooking utensils, appliances, and building materials. In combination with other substances, aluminum is an ingredient in such everyday items as antacids and antiperspirants.

Limited amounts of aluminum can be found in natural waters, drinking water, and air. It makes up approximately 8 percent of the earth's crust; however, higher concentrations may exist in soil surrounding waste sites associated with industries such as coal combustion and aluminum mining and smelting.

Very little aluminum enters the body through the skin or inhalation, and the small amount that might enter the bloodstream through the stomach is quickly eliminated. Some people may get skin rashes from aluminum in antiperspirants, and factory workers who

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breathe in large amounts of aluminum dust can have lung problems such as coughing or changes that show up in chest x-rays. People with Alzheimer's disease have more than the usual amount of aluminum associated with lesions found in their brain tissue, but there is insufficient evidence to conclude that aluminum causes this disease.

No cases of cancer have been attributed to aluminum exposure and, in general, exposure to aluminum is usually not considered harmful to humans.

Antimony

Antimony is a naturally occurring element that can be found in the environment in a variety of mineral forms. It is used industrially in metal alloys and for producing fireproofing chemicals, ceramics, glassware, and pigments. Antimony has also been used medicinally as an antiparasitic agent. Antimony occurs naturally in air, soil, food, and water at very low levels. Much of the antimony in the environment is bound tightly to dust, soil, and rocks. However, people can breathe high levels of antimony in dust if they live near antimony mines or processing companies.

Antimony can enter the body by absorption from the gastrointestinal tract following ingestion of food or water containing antimony, or by absorption from the lungs after inhalation. Ingestion of high doses of antimony can result in burning stomach pains, colic, nausea, and vomiting. Long-term occupational inhalation exposure has caused heart problems, stomach ulcers, and irritation of the lungs, eyes, and skin.

The critical or most sensitive noncarcinogenic effects of exposure to antimony are shortened lifespan, reduced blood glucose levels, and altered cholesterol levels. Existing data suggest that antimony may be an animal carcinogen but are not sufficient to justify a quantitative cancer potency estimate at this time. In laboratory rats, inhalation of antimony dust can increase the risk of lung cancer. However, there is no evidence of increased risk of cancer to animals from eating food or drinking water containing antimony. It is not known whether antimony can cause cancer in humans.

Arsenic

Arsenic is a naturally occurring element and is usually found combined with one or more elements, such as oxygen or sulfur. This element is widely distributed in the environment from natural sources, but higher concentrations have been found to occur in association with chemical waste, smelting of copper and other metals, fossil fuel combustion, and pesticide use. The primary use of arsenic is as a wood preservative, but it is also used to make insect and weed killers and pharmaceuticals.

All people are exposed to low levels of arsenic because it is naturally occurring and low levels are present in food, water, soil, and air. Workers in several industries (nonferrous smelting, wood preservation, arsenical pharmaceutical production, and the production and application of arsenical pesticides) may be exposed to significantly higher levels. Since ancient times, arsenic has been recognized as a human poison. Large oral doses can kill.

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Chronic arsenic overexposure may cause many health effects including body weight changes. changes in the blood, and liver and kidney damage. The critical or most sensitive effects, based on chronic oral exposure to humans, are hyperpigmentation, keratosis, and possible vascular complications.

Arsenic is considered a Group A human carcinogen by EPA. Epidemiologic studies and case reports have found evidence that arsenic exposure is associated with increased risk of cancer of the skin, lungs, bladder and kidneys. In workers exposed by the inhalation pathway, increased risk of lung cancer is the major carcinogenic effect. If humans are exposed by the oral route, the major carcinogenic effect is an increased risk of skin cancer.

Barium

Barium is a naturally occurring element that makes up 0.05 percent of the earth's crust. Barium compounds are used commercially in the metallurgic, paint, glass, ceramic, and electronics industries and for medicinal purposes.

Background levels of barium in the environment are very low. Barium can enter the body by inhaling air or ingesting food or water containing barium or its compounds. Little is known about the human health effects of barium. Most of the reported data come from short-term exposure to large amounts of barium. Ingestion of barium can cause many effects including: breathing difficulty; increased blood pressure; changes in heart rhythm, blood, and nerve reflexes; stomach irritation; swelling of the brain; and damage to the liver, kidney, heart, and spleen.

The critical or most sensitive effect from oral exposures, seen in animal studies, is a significant increase in blood pressure. Other long-term effects are changes in function and chemistry of the heart and reduced life span. Adverse effects associated with inhalation of barium dusts have not been well characterized. Smaller litter size and increased miscarriage in rats have been reported as critical effects from inhalation of barium.

There is no reliable information to determine whether barium can cause cancer in animals or people.

Beryllium

Pure beryllium is a hard gray metal. In nature it occurs as a chemical component of certain rocks. The minerals bertrandite and beryl are mined commercially for recovery of beryllium.

Most beryllium ore mined is processed into pure metal, alloys, or beryllium oxide. Beryllium metal and alloys are used in electronics, aircraft and space craft structures, X-ray machines, nuclear weapons, and nuclear reactors. Beryllium oxide is used in the manufacture of specialty ceramics.

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Beryllium is released into the air by natural sources such as volcanic dust, however the major emission source to the environment is the burning of fossil fuels. Beryllium compounds are naturally present in soils, but deposition of atmospheric beryllium and disposal of beryllium-containing wastes can increase the levels in localized areas. The general population is exposed to low levels of beryllium in air, food, and water. Beryllium occurs naturally in tobacco and can be inhaled in cigarette smoke.

Industrial workers have the highest exposure to beryllium in the mining, milling, and processing of beryllium ore to alloys or beryllium oxide. In general, the primary route of exposure to beryllium is inhalation, since relatively little beryllium is absorbed from the gastrointestinal (GI) tract or through the skin.

The respiratory tract is the major target of inhalation exposure to beryllium. Shortterm exposure can produce lung inflammation and pneumonia-like symptoms. Long-term exposure can cause berylliosis, an immune reaction characterized by noncancerous growths on the lungs. Similar growths can appear on the skin of sensitive individuals exposed by dermal contact.

Epidemiological studies have found that an increased risk of lung cancer may result from exposure to beryllium in industrial settings. In addition, laboratory studies have shown that breathing beryllium causes lung cancer in animals. However, it is not clear what cancer risk, if any, is associated with ingestion of beryllium.

EPA has classified beryllium as a Group B2, probable human carcinogen based on the limited human evidence and the animal data (Table 4-2). The International Agency for Research on Cancer (IARC), has concluded there is sufficient evidence that beryllium is an animal carcinogen, but limited human evidence. Considering both the animal and human studies together, IARC concludes beryllium should be suspected of being a human carcinogen.

BHC (benzenehexachloride)

BHC is a man-made chemical that occurs in eight forms or isomers. The isomers alpha (α) , beta (β) , gamma (γ) , and delta (δ) are all solids that were used primarily as pesticides. The γ isomer, also called lindane, was the active component in pesticide formulations. Commercial lindane contains a mixture of the isomers. The BHC insecticides were used on fruit, vegetable, and forest crops. Lindane is also used as a human medicine for head and body lice and scabies. Since the late 1970s, BHC has not been used as a pesticide in the United States, and manufacture of lindane stopped. Lindane is still imported for use in consumer products including dog dips, shampoos, lotions, sprays, and creams.

Although no longer used as a pesticide, former widespread use of BHC pesticides has left α , β , γ , and δ isomers in the air, water, and soil. In general, lindane is degraded poorly in the environment, but does biodegrade slowly in soil and aerated water.

Human exposure can occur through contact with contaminated air, water, or food. BHC is found in meat and milk as well as fruit and vegetables. In the body, BHC is

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absorbed rapidly from the digestive tract. In addition, lindane can absorb through the skin when used in lotions, creams, and shampoos.

Data on human exposure comes primarily from occupational studies. BHC overexposure can cause lung irritation, heart disorders, and blood disorders. Accidental and suicidal poisonings have caused death in some cases.

Long-term exposure to high doses has caused convulsions, kidney disease, liver disease, and death in laboratory animals. BHC was removed from use as an insecticide because long-term exposure to the α , β , and γ isomers caused liver cancer in mice. EPA has classified α and γ BHC as Group B2, probable human carcinogens, based on animal data (USEPA 1994).

2-Butanone (Methyl Ethyl Ketone [MEK])

MEK is a volatile liquid with a sharp sweet odor. It is manufactured in large amounts for use as a solvent and as a component of products such as paints, glues, and coatings. MEK is also synthesized naturally by some trees and other plants. The exhaust of cars and trucks releases MEK into the air. In addition, MEK is often found in the air, water, and soil of landfills and chemical waste sites.

People are likely to be exposed to MEK in the air from drying paints and glue. Workers in many industries are exposed to MEK, and the general public near manufacturing plants can be exposed to MEK in the air and water. In cities, MEK is found often in the air and occasionally in the municipal water supplies. Lastly, it has been determined MEK occurs naturally in some foods including: chicken, roasted nuts, cheese, fruit, dried beans, split peas, and lentils.

Greater than 50 percent of the inhaled dose of MEK is absorbed into the body. It is unknown how much of the oral and dermal doses are absorbed. Humans can smell MEK at levels below those that cause health effects. At levels slightly above the odor threshold, people have reported mild irritation to the nose, throat, eyes, and skin.

In general, there are only observable effects at high doses in animal studies. Health effects resulting from inhalation or ingestion of MEK include: respiratory irritation, kidney and liver abnormalities, underdeveloped offspring, and unconsciousness and death at high doses. Toxic effects to offspring is the EPA's critical or most sensitive effect. There are reports of behavioral effects in mice and baboons at low doses of MEK.

There is very little long-term exposure data for MEK in humans and animals. It is unknown whether MEK causes cancer in animals or humans.

Cadmium

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Cadmium is a naturally occurring element present in trace amounts in the earth's crust. Cadmium has several industrial applications but it is used mostly in metal plating and the manufacture of pigments, batteries, and plastics.

Humans are exposed to small quantities of cadmium because it is widely distributed in air, water, soil, and food. Cadmium can enter the body by absorption from the stomach or intestines after ingestion of food or water containing cadmium, or by absorption from the lungs after inhalation of cadmium-containing dust, mists, or fumes. Food and cigarette smoke are probably the largest sources of cadmium for the general public. Very little cadmium enters the body through the skin.

Cadmium can cause a number of adverse health effects. Ingestion of high doses causes severe irritation to the stomach, leading to vomiting and diarrhea, while inhalation can lead to severe irritation of the lungs and may cause death. People have committed suicide by drinking water containing high levels of cadmium. There is very strong evidence that the kidney is the main target organ of cadmium toxicity following chronic exposure. Long-term ingestion of cadmium has caused kidney damage and fragile bones in humans. Long-term human exposure by the inhalation route may cause kidney damage and lung disease such as emphysema. The most sensitive or critical effect of cadmium exposure is significant proteinuria, indicative of abnormal kidney function.

Long-term inhalation of air containing cadmium by workers is associated with an increased risk of lung cancer. Laboratory rats that breathe cadmium have increased cancer rates. Studies of humans or animals have not demonstrated increased cancer rates from eating or drinking cadmium. EPA classifies cadmium as a Group B1, probable human inhalation carcinogen based on occupational studies (Table 4-2).

Calcium

Calcium, an essential nutrient and the most abundant metallic element in the human body, is used as an alloying agent; as a deoxidizer; as a getter in electron tubes; as a reducing agent in the preparation of some metals; and as a dehydrating agent for organic liquids. It occurs in limestone, chalk, marble, dolomite, eggshells, and the shells of many marine animals.

Calcium is absorbed in the small intestine. However, calcium absorption is under homeostatic metabolic control, meaning that it is controlled so that calcium concentrations in the body remain within a narrow range. Substances such as oxalic acid, phytic acid, fat, fiber, and phosphates that form strong complexes or insoluble compounds with calcium reduce its absorption. Infants and children absorb up to 60 percent of ingested calcium; pregnant women, about 50 percent; and other adults, about 30 percent. The presence of sufficient levels of calcium in body tissues helps to prevent deficiency symptoms and disease caused by poor mineralization of bones (osteoporosis) and teeth, softening of bony tissue, deformity of bones in rickets, and impairment of normal growth. Calcium also affects blood pressure through its action on the muscle cells in the artery walls. An excess of calcium inside these cells causes muscular contraction, which narrows the arteries and increases blood pressure.

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The contraction process also involves hormones, sodium, and potassium. A possible explanation for the calcium-hypertension connection is that when calcium intake is low, the artery muscle cells "collect" the calcium and contract, raising blood pressure.

The excretion and deposition of calcium is regulated by hormones sensitive to blood levels of calcium. Excess calcium is excreted except in hormonal imbalance states; excess calcium may result in kidney stone formation and this is particularly true when calcium supplements are taken. When rats were fed dibasic calcium phosphate (a calcium supplement) as their sole calcium source, they deposited abnormally high amounts of calcium in their kidneys. Dibasic calcium phosphate also inhibits magnesium absorption and if the calcium phosphate is fortified with magnesium, it interferes with iron absorption.

Calcium is not classified by the EPA as to its carcinogenic potential.

Chlordane/Heptachlor/Heptachlor Epoxide

Chlordane and heptachlor are man-made pesticides that were once widely used on more than 20 types of crops and in household applications to eliminate termites. Most uses were banned in the United States by 1988 because of concerns about carcinogenicity and the persistence of these compounds in the environment. Commercial chlordane is a mixture of more than 50 different compounds composed primarily of cis-chlordane, trans-chlordane, and heptachlor. Similarly, technical-grade heptachlor contains chlordane, trans-chlordane, and heptachlor.

Both chlordane and heptachlor degrade slowly in the environment. Heptachlor is converted by chemical and microbial reactions to heptachlor epoxide, which is more persistent and more toxic than the parent compound. Since chlordane and heptachlor were used on food crops and in homes, there are residual levels in soils, ambient air, and indoor air in many parts of the United States. These compounds are taken up by plants and can biomagnify in the food chain.

Chlordane and heptachlor can be absorbed by the body through dermal contact, inhalation of vapors in ambient air, and ingestion of contaminated soil or food. These chemicals and their metabolites, including heptachlor epoxide, may remain stored for months or years in the blood plasma or the body fat of the liver, spleen, brain, and kidneys.

Little data are available on the adverse health effects of chlordane and heptachlor exposure in humans. Symptoms associated with human overexposure to chlordane and heptachlor include headache, dizziness, lack of coordination, irritability, weakness, and convulsions. In humans, an acute oral lethal dose of chlordane was estimated by the World Health Organization (WHO) (1984) to be between 25 and 50 mg/kg.

Experimental studies exploring the health effects on animals exposed to levels of chlordane between 5 and 1,000 ppm showed an association between exposure and immunologic dysfunction, reproductive dysfunction, nervous system damage, liver damage,

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convulsions, liver cancer, and death. The critical effect associated with lower doses is increased liver size.

Some occupational epidemiology research supports an increased cancer risk associated with human exposure to chlordane. Chronic oral treatment with chlordane and heptachlor has resulted in significant increases in hepatocellular carcinomas in mice. The EPA has classified chlordane, heptachlor, and heptachlor epoxide as Group B2, probable human carcinogens.

Chromium

Chromium is a naturally occurring element used industrially in the manufacture of steel and other alloys. Its compounds are used in refractory brick for the metallurgical industry, and in metal plating (chromium VI), the manufacture of pigments (both chromium III and chromium VI), leather tanning (chromium III), and other processes. Exposure to chromium can result from inhalation of air containing chromium-bearing particles and ingestion of contaminated water or food. Chromium is considered an essential nutrient that helps to maintain normal glucose, cholesterol, and fat metabolism. The minimum daily requirement of chromium for optimal health has not been established, but ingestion of 20 to $500~\mu g/day$ has been estimated to be safe and adequate.

The two major forms of chromium found in the environment differ in their potential adverse health effects. Chromium VI is an irritant, and short-term, high-level exposure can result in adverse effects at the site of contact, causing ulcers of the skin, irritation and perforation of the nasal mucosa, and irritation of the gastrointestinal tract. Minor to severe damage to the mucous membranes of the respiratory tract and to the skin have resulted from occupational exposure to as little as 0.1 mg/m³ chromium VI compounds. The critical effect associated with inhalation of chromium VI is atrophy of the nasal mucosa. Chronic oral exposure to chromium VI may also cause adverse effects in the kidney and liver. Long-term occupational exposure to low levels of chromium VI compounds has been associated with lung cancer in humans. EPA has classified chromium VI as a Group A human inhalation carcinogen (Table 4-2).

The second form, chromium III (Cr 3⁺), does not result in these effects and is the form thought to be an essential nutrient. The only effect observed in toxicological studies of chromium III was a decrease in liver and spleen weights in rats. Chromium III has not been assigned a weight-of-evidence classification for carcinogenicity by EPA.

Cobalt

Cobalt occurs naturally in many different chemical forms. Pure cobalt is a steel-gray, shiny, hard metal that does not dissolve in water. Natural sources of cobalt include soil and dust, seawater, volcanic eruptions, and forest fires. In the United States cobalt is used to make alloys, as a drier for paint and porcelain enameling used on steel bathroom fixtures, large appliances, and in making colored pigments. Man-made sources include byproducts of burning of coal and oil, exhaust from cars, trucks, and aircraft, industrial processes that use the metal or its compounds, and sewage sludge from cities.

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Cobalt stimulates production of red blood cells in humans and is also used as treatment for anemia. It has been found to be a sensitizer in humans. Individuals are sensitized following dermal or inhalation exposure, but ingestion of cobalt may also trigger dermatitis. The most sensitive indicators of cobalt toxicity by inhalation exposure are the effects on the respiratory system in both humans and animals. Interrelationships have been found to exist between cobalt and nickel sensitization and it is possible that in people sensitized by nickel, exposure to cobalt may result in an allergic reaction. Indicators of cobalt toxicity following oral exposure include an increase in hemoglobin in both humans and animals and dermatitis in sensitized individuals. Following chronic occupational exposure. cobalt was found to be the cause of hard metal disease. Observed symptoms include respiratory irritation, wheezing, asthma, pneumonia, and fibrosis. These effects have been found to occur at exposure levels ranging from 0.003 to 0.893 mg/m³ over a period of 2 to 17 years. Work-related asthma was found in hard metal workers who were occupationally exposed to levels of cobalt ranging from 0.007 to 0.893 mg/m³. The only known nutritional but vital function of cobalt is as a cofactor of vitamin B12, and there is no evidence that the intake of cobalt is deficient in the human diet; therefore, no RDA is deemed necessary for cobalt. The acceptable daily intake of cobalt in humans ranges from approximately 0.002 through 0.008 mg cobalt/kg/day in adults and 0.01 to 0.06 mg cobalt/kg/day in children.

Copper

Copper is a naturally occurring element that is used to make electrical wiring and water pipes and is a component of alloys such as bronze and brass. Copper compounds are used in gardening supplies to prevent plant disease, in water treatment and in wood, leather, and fabric preservatives.

Copper may enter the body by inhalation, by ingestion of water, or food containing copper, and by dermal contact. Copper is an essential element at low-dose levels but may induce toxic effects at high-dose levels. The National Academy of Sciences has recommended 2 to 3 mg/day of copper as a safe and adequate daily intake. Long-term overexposure to copper dust can irritate the nose, mouth, and eyes and cause headaches, dizziness, nausea, and diarrhea. Ingestion of high concentrations of copper can cause vomiting, diarrhea, stomach cramps, and nausea. Liver and kidney damage and possibly death may occur if exposure continues.

Very young children are particularly sensitive to liver damage from overexposure to ingested copper. In general, the seriousness of health effects of copper increase as the level and duration of exposure increases. Copper is not known to cause cancer or birth defects.

DDT/DDE/DDD

Dichlorodiphenyltrichloroethane (DDT) is a manmade chemical that has been used extensively throughout the world as a broad-spectrum insecticide. Technical grade DDT typically contains 80 to 90 percent 4,4'-DDT as well as other components including dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE). Although the agricultural use of DDT in the United States was banned by the EPA in 1972, it

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is presently widely distributed in the environment as a result of its extensive past use and its high stability and persistence.

Absorption of DDT has been demonstrated following oral, inhalation, and dermal exposure. The primary route of exposure, however, is the oral route.

The major adverse effects of DDT appear to involve the nervous system, the liver, and reproduction and development of offspring. In humans, doses of up to 6 mg/kg usually produce no general illness, but headaches, excessive perspiration, and nausea have sometimes been reported after DDT exposure to higher doses. Vomiting due to nervous system effects rather than gastrointestinal irritation has been reported in humans at doses of about 10 mg/kg, and convulsions occurred at about 16 mg/kg.

At lower doses (250 mg), noted effects are limited to prickling sensations on the tongue and mouth. Intermediate doses (750 mg) were reported to produce sensitivity of the lower part of the face, uncertain gait, cold moist skin, and hypersensitivity to contact. A dose of 1,500 mg produced prickling of the mouth and nose, disturbance of equilibrium, dizziness, confusion, tremors, malaise, headache, fatigue, and severe vomiting. All of the human volunteers orally exposed to DDT at doses of 250 to 1,500 mg recovered within 24 hours.

Although there is insufficient evidence to classify DDT, DDE, or DDD as carcinogens based on human studies, they have been found to be carcinogenic in a number of animal studies, primarily producing liver tumors. EPA classifies DDT, DDE, and DDD as Group B2 probable human carcinogens.

Dieldrin

Dieldrin is a man-made chemical that was used extensively as an agricultural pesticide for over 20 years until its use was suspended by the USDA in 1970. Use of dieldrin to control termites continued until 1987, when the manufacturer voluntarily canceled the registration. Although not used for several years, dieldrin persists in the environment and can be found tightly bound to soils and sediment. Dieldrin is also present as the breakdown product of the related pesticide aldrin.

Plants can take up dieldrin from soil. In animals, dieldrin concentrates in fat. Fish and livestock can accumulate high concentrations through the food chain.

Dieldrin can be absorbed into the body through skin contact, ingestion and inhalation. The most likely route of human exposure to dieldrin is through eating contaminated food. Foods most likely to be contaminated include fish, shellfish, root crops, meat, and dairy products.

Human poisoning from dieldrin is characterized by major voluntary muscle convulsions or kidney damage that can be fatal. Other effects include malaise, uncoordination, headache, dizziness, and gastrointestinal disturbances. Animal studies show effects of dieldrin on the nervous system and kidneys similar to the effects in humans. In

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addition, dieldrin exposure has resulted in increases in liver enzymes and liver weight. decreased immune response, and high mortality in nursing rat pups. Liver damage is the critical or most sensitive effect in animals according to EPA. It is unknown whether humans exposed to dieldrin have similar health effects.

Dieldrin is a carcinogen in mice, with the liver being the site of increased tumor incidence. However, there is insufficient evidence to classify dieldrin as a human carcinogen. Dieldrin is classified by EPA as a Group B2, probable human carcinogen.

Endosulfan

Endosulfan is a man-made broad spectrum insecticide in the family of polycyclic chlorinated hydrocarbons. The technical grade contains a mixture of endosulfan I and endosulfan II. EPA restricted its use in the 1970s but endosulfan is still used on vegetables, fruit, tobacco, and cotton in the United States.

Endosulfan, a brown crystalline solid in its pure form, is used in several different states. It is formulated as a dust, a wettable powder, as granules, or an emulsion. It is an insecticide that kills a broad range of different insects.

In the environment, endosulfan is stable in soil. Plants and animals convert endosulfan to a variety of derivatives. The most common, endosulfan sulfate, is toxic to animals.

Humans can be exposed to endosulfan in air, soil, water, and food. In general, most people would be exposed by eating food contaminated with endosulfan. It is not clear whether endosulfan bioconcentrates, but theoretically it could. Endosulfan adheres tightly to soil and does not dissolve in water. Only small amounts of endosulfan are found in groundwater. However, large amounts of endosulfan have been found in surface water, presumably due to small soil particles.

Short-term occupational exposure to high concentrations of endosulfan by inhalation, dermal contact, or poisoning by ingestion have similar nervous system effects. Minor effects include headaches and dizziness. More severe effects include hyperactivity, convulsions, coma, and death. The health effects in people exposed to low levels for long periods are unknown.

Long-term low dose rodent testing has not shown nervous system effects. Rather, only the kidneys and reproductive organs are negatively affected. Similar effects have not been seen in humans. Laboratory testing has been done primarily on rats, mice, and guinea pigs. However, it was discovered that cows are much more sensitive to the nervous system effects than most laboratory animals.

Endrin/Endrin Aldehyde

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Endrin is a man-made insecticide that was used primarily on cotton and grains. There are currently severe restrictions on the use of endrin in the United States. Endrin aldehyde is a very small component of technical-grade endrin and is also a degradation product of endrin that is produced at high temperatures and over long periods of time.

Endrin is very persistent in the environment. It is insoluble in water and adsorbs tightly to soil particles making it nearly immobile in the subsurface. Small amounts of endrin may volatilize from soil or be carried by dust particles in the air.

Humans could be exposed to endrin by breathing contaminated air, drinking contaminated water or by coming into direct contact with contaminated soil or crops. The most likely route of possible exposure is ingestion of contaminated food products.

Endrin can be absorbed by the body through the skin, the lungs and the stomach. In general, it is quickly metabolized and the metabolites are quickly eliminated from the body. Endrin has been found to accumulate in the bodies of laboratory animals, primarily in the fatty tissues.

Exposure to endrin in humans can effect the central nervous system, and in some cases, causes death. In mild poisoning cases, however, recovery is usually rapid with no permanent effects.

The critical or most sensitive effects of endrin that serve as the basis of EPA's RfD are convulsions and liver lesions. Endrin has exhibited no evidence of carcinogenicity in either humans or animals; however, the available studies are regarded by EPA as inadequate and inconclusive.

Iron

Iron is a naturally occurring metallic element. It is commonly used to produce steel, special-purpose alloys with magnetic properties, and heat, corrosion and electrical resistances. In combination with other substances, iron is used to make pigments, polishing compounds, catalysts, feeds, disinfectants, and sewage and industrial wastewater treatment chemicals.

Iron is an essential nutrient; required for maintenance of good health. Available data indicate that to protect against the adverse health effects associated with iron deficiency, the RDA (recommended dietary allowance) should be at least 30 mg/day for pregnant women. If ingested in larger quantities iron can be toxic, causing effects such as irritability, seizures, abdominal pain, vomiting, diarrhea, lethargy, and coma. However, apart from accidental or deliberate poisoning, ingestion of sufficient iron to cause these effects is unlikely in most individuals.

Approximately 0.01% of the body burden of iron is excreted daily and the elimination half-time of iron from the body is 10 to 20 years. Humans do not have a mechanism to increase the excretion of absorbed iron in response to elevated body levels. Chronic ingestion

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of high levels of iron causes an increase in tissue iron levels. During iron overload, excess iron is stored as hemosiderin in the liver and other organs. Excessive hemosiderin deposits in the liver can lead to liver cirrhosis. The recommended dietary allowance of iron for infants is 1.0 mg/kg each day, however, this level could lead to iron overload in some adults.

There is no evidence that iron can cause cancer.

Lead

Lead is a naturally occurring metal that is used in the manufacture of storage batteries and the production of ammunition and miscellaneous metal products (e.g., sheet lead, solder, and pipes). Other uses for lead are in the manufacturing of lead compounds including gasoline additives and pigments. In recent years, the quantity of lead used in paints, gasoline additives, ammunition, and solder has been reduced because of lead's toxic effects.

Lead can enter the body via ingestion and inhalation. Although it may also enter the body through the skin, dermal absorption of inorganic lead compounds is of less concern than absorption through other routes. Children appear to be the segment of the population at greatest risk from toxic effects of lead. Children absorb about 50 percent of ingested lead while adults absorb only 5 to 15 percent. Initially, lead travels in the blood to the soft tissues (heart, liver, kidney, brain, etc.), then it gradually redistributes to the bones and teeth where it tends to remain. Children retain a larger fraction of the absorbed lead, about 57 percent, in the blood and soft tissue compartments whereas in adults roughly 95 percent of the total body burden of lead is found in bones and teeth.

The most serious effects associated with markedly elevated blood lead levels include neurotoxic effects such as irreversible brain damage. Health effects are the same for inhaled and ingested lead. At blood levels of 40 to 100 micrograms per deciliter (μ g/dL) children have exhibited nerve damage, permanent mental retardation, colic, anemia, brain damage, and death. Chronic kidney disease is also evident at these lead levels. For most adults, such damage does not occur until lead levels exceed 100 to 120 μ g/dL in blood. At lower levels, lead can cause a variety of subtle neurological effects, especially in small children. Blood levels as low as 10 μ g/dL have been associated with lower intelligence quotient (IQ) scores and cognitive deficits in children.

None of the epidemiology studies conducted to explore the relationship between lead exposure and increased cancer risk in humans found any relationship. However, animal studies have shown increased kidney cancer and central nervous system (CNS) cancer in rats and mice orally exposed to lead. The EPA has classified lead as a Group B2, probable human carcinogen.

Magnesium

Magnesium, an essential nutrient and cofactor of many enzymes, is used in lightweight alloys, as an electrical conductive material and for incendiary devices such as flares. Magnesium is absorbed primarily in the small intestine and calcium and magnesium

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compete with respect to absorptive sites; and excess calcium may inhibit magnesium absorption.

Magnesium oxide can cause metal fume fever if inhaled in sufficient amounts. Conjunctivitis, runny nose, and coughing up discolored sputum results from industrial inhalation exposures. Increases in serum magnesium up to twice the normal levels failed to produce ill effects, but were accompanied by calcium increases. Intoxication occurring after oral administration of magnesium in salts is rare, but may occur if the individual is already suffering from kidney impairment. Large doses of magnesium have been taken in the form of the laxative Epsom salts, without ill effects except diarrhea.

Manganese

Manganese is a naturally occurring element used in the steel industry, metallurgical processing, and as a component of dry cell batteries. Manganese is an essential element for humans and is a cofactor for a number of enzymatic reactions. A WHO committee concluded that an intake of 2 to 3 mg/day was inadequate for adults.

Following inhalation of manganese dust, absorption into the bloodstream occurs only if particles are sufficiently small to be able to penetrate deeply into the lungs. Long-term inhalation of manganese dust may result in a neurological disorder characterized by irritability, difficulty in walking, and speech disturbances. Short-term inhalation exposure has been associated with respiratory disease.

There are few reports of negative health effects in humans exposed to manganese in drinking water or food. Laboratory studies of animals exposed to manganese in water or food have demonstrated adverse health effects including changes in brain chemical levels, low birth weights in rats when mothers were exposed during pregnancy, slower than usual testes development, decreased body weight gain, and weakness and muscle rigidity in monkeys.

There are no human carcinogenicity data for manganese exposure. The data from some animal studies have shown increases in tumors in a small number of animals at high doses of manganese, but the data are inadequate to judge whether manganese can cause cancer. EPA has judged manganese not classifiable as to human carcinogenicity (Group D).

Mercury

Mercury is a naturally occurring element that exists in three oxidation states--metallic mercury (Hg⁰), mercurous mercury (Hg⁺), and mercuric mercury (Hg²⁺)--and a variety of chemical forms. The most important with respect to human exposure are compounds of methyl mercury and mercuric mercury, as well as elemental mercury vapor.

Uptake of inorganic mercury and methyl mercury compounds is primarily through ingestion, with the major source of human exposure to methyl mercury being through the consumption of fish and shellfish. Mercury can also enter the body readily through inhalation of mercury vapor.

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All forms of mercury, once absorbed, are distributed to tissues throughout the body via the bloodstream. The critical, or most sensitive, effect of inorganic mercury is kidney damage and CNS damage. Long-term exposure to all forms of mercury can permanently damage the brain, kidneys, and developing fetus. The form of mercury and route of exposure determine which health effects will be most severe. Mercury vapor and methyl mercury readily cross the blood-brain and placental barriers.

Prenatal life is very sensitive to methyl mercury poisoning, with subsequent effects in infants ranging from slowed mental and coordination development to a severe form of cerebral palsy. To date, these effects have been found to be irreversible. Depending upon the form, the level of mercury taken in, and the duration of exposure, effects on the adult nervous system can range from reversible feeling of burning, or pins and needles, and feeling "out-of-sorts" to irreversible brain damage leading to permanent tremors and shakiness, and constriction of the visual field.

Mercury has not been found to be carcinogenic in animals or humans.

Methylene Chloride (Dichloromethane, MC)

MC is a man-made liquid chemical that is widely used as an industrial solvent and as a paint stripper. Because MC evaporates easily, most MC released into the environment will end up in the air. Small amounts of MC may be found in some drinking water. Absorption into the body occurs readily following exposure by breathing vapors or accidental ingestion. Occupational worker exposure to MC in air has resulted in drowsiness, fatigue, lack of appetite, and light-headedness. Other effects include impaired reaction time and coordination, numbness or tingling of fingers and toes, and intoxication. The critical, or most sensitive, effect of MC exposure is liver damage observed in rats treated with MC.

Chronic exposure of laboratory animals to high concentrations of MC by inhalation resulted in an increased incidence of liver and lung cancer in mice and rats. MC has not been shown to cause cancer in occupationally exposed humans. Based on results from animal studies, MC is classified as a Group B2-probable human carcinogen.

Nickel

Nickel is a naturally occurring metal found in small quantities in the earth's crust. Nickel is used industrially in making various steels and alloys and in electroplating. Exposure to nickel and nickel compounds may occur through inhalation of dust and particles, ingestion of food and drinking water containing nickel, and by absorption through the skin. Nickel has been shown to be essential nutrients for some species of animals and may be essential to humans.

Inhalation exposure to high levels of nickel and nickel compounds may have adverse effects on the lungs. Exposure by oral and inhalation routes may also affect the immune system, kidneys, and blood. Inhalation of nickel at concentrations greater than 0.001 mg/m³

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in air may cause immune system depression, lung irritation, and pulmonary disease. Death may result from inhalation of concentrations greater than 0.1 mg/m³.

Inhalation of nickel refinery dust has caused cancer of the lung, nasal cavity, and voice box in humans. Nickel refinery dust and nickel subsulfide have been classified as Group A human carcinogens. It is not known if other nickel compounds are carcinogenic.

Phthalic Acid Esters (Bis(2-ethylhexyl)phthalate, Butyl benzyl phthalate, Di-n-butyl phthalate, Di-n-octyl phthalate)

Phthalic acid esters (PAEs) are used as plasticizers which impart flexibility to plastics and which may comprise as much as 50% by weight of the final product. Virtually all PAEs produced are used to manufacture other products. Approximately 98% of the United States supply is incorporated into various plastic products; most of these are ultimately deposited at landfill sites. The remaining 2% is distributed among other products such as pesticides, cosmetics, and paints (USEPA 1981).

PAEs, including bis(2-ethylhexyl)phthalate (BEHP), butyl benzyl phthalate, di-n-octyl phthalate, and di-n-butyl phthalate, generally occur as colorless liquids with low water solubility; high solubility in oils and organic solvents; and, for the higher molecular weight compounds, low volatility. They are ubiquitous in the environment. Sources of PAEs in the environment include releases from industrial facilities and landfills, leaching and volatilization from PAE-containing products, and incomplete burning of plastics. PAEs released to air tend to adsorb to airborne particulate matter which then deposits on land and water surfaces. Most PAEs released to water tend to adsorb to soil and sediment. When PAEs are released to soil, they usually do not migrate far from where they are released, though the presence of organic solvents or humic acids in the soil can increase mobility. Biodegradation is a major fate process for PAEs; however, BEHP biodegrades slowly and can be persistent in the environment. PAEs are taken up by plants and animals, and bioconcentration has been reported in fish and shellfish; however, because PAEs are metabolized, biomagnification through the food chain is unlikely.

Human exposure to the PAEs can occur through food consumption and use of PAE-containing products as well as via contact with contaminated water and soil. Food consumption is the major route of exposure to PAEs for the general public. Fish and other seafood are frequently contaminated, especially in industrialized areas. Additionally, PAEs can leach into foods from plastic packaging, particularly foods with high fat content. Exposure to PAEs in ambient air is generally low, however, volatilization from plastics in flooring, furniture, and other products may result in higher indoor air concentrations. Skin contact with PAEs in products such as cosmetics and insect repellents would result in higher exposure. Humans who receive blood transfusions or hemodialysis therapy may also be exposed to PAEs leached from tubing and fluid storage bags used in medical practice; though this exposure is widespread, only a small subpopulation would receive continuous exposure.

There is very little information on absorption from PAEs by humans, however, limited human data and animal studies indicate that PAEs are absorbed to some extent by the

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oral, inhalation, and dermal routes. Studies indicate that PAEs and their metabolites are found primarily in adipose tissue, the liver, kidney and intestines but accumulation and retention of these compounds is minimal. PAEs and their metabolites are eliminated through the urine, feces, and bile.

Data on the effects of PAEs in humans, particularly for oral exposure, are limited. The low levels to which humans are routinely exposed do not appear to cause adverse health effects. Animal studies indicate that the toxicity of PAEs is low and generally tends to be inversely related to the molecular weight of the compound. Subchronic and chronic toxicity effects include decreased body weight and increased liver and kidney weights. Target organs of PAEs include the testes and the liver, although adverse effects to these organs have not been observed with all PAEs. Testicular atrophy has been associated with exposure to BEHP, butyl benzyl phthalate, and di-n-butyl phthalate. Hepatic effects commonly reported include enlargement of the liver, effects on the mitochondria, and decreased succinate dehydrogenase activity. Reproductive effects have been reported following exposure to PAEs during mating and gestation. BEHP and di-n-butyl phthalate have been shown to decrease fertility and reproductive performance in mice. Based on critical effects observed in animal studies, the EPA has derived reference doses for: BEHP and butyl benzyl phthalate based on increased liver weight; di-n-octyl phthalate based on increased liver and kidney weight; and di-n-butyl phthalate based on increased mortality.

There is no conclusive evidence that PAEs are human carcinogens; however, two PAE have been shown to be carcinogenic in animal studies. BEHP and butyl benzyl phthalate have been tested in 2-year carcinogenesis bioassays performed by the National Toxicology Program. BEHP was found to cause increased incidence of hepatocellular carcinomas in both rats and mice. There was limited evidence that butyl benzyl phthalate induces leukemia in female rats. EPA has classified BEHP as a Group B2, probable human carcinogen and butyl benzyl phthalate as a Group C, possible human carcinogen.

Polynuclear Aromatic Hydrocarbons (PAHs)

PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular, or cluster arrangements. PAHs are formed during the incomplete burning of fossil fuel, garbage, or any organic matter. PAHs produced by burning may be carried into the air on dust particles and distributed into water and soil. In general, PAHs do not evaporate easily and do not dissolve in water.

Exposure to PAHs may occur by inhaling airborne particles, drinking water, or accidentally ingesting soil or dust containing PAHs. In addition, smoking tobacco or eating charcoal-broiled food are common routes of exposure to PAHs.

Some PAHs are known carcinogens, and potential health effects caused by PAHs are usually discussed in terms of an individual PAH compound's carcinogenic or noncarcinogenic effects. Little attention has been paid to noncarcinogenic effects of PAHs. Rapidly growing tissues, such as the intestinal lining, bone marrow, lymphoid organs, blood cells, and testes

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seem to be especially susceptible targets to noncarcinogenic effects. Concentrations of 150 mg/kg or more administered to laboratory animals have been shown to inhibit body growth.

Exposure to benzo(a)pyrene (B(a)P) and other carcinogenic PAHs can cause cancer at the point of exposure. However, only B(a)P has been assigned a slope factor by EPA. In the past, other Group B2 carcinogenic PAHs were assumed to be equipotent to B(a)P, however, it has been shown in animal studies that some are less carcinogenic than B(a)P. EPA Region I has recently adopted relative potency factors (RPF) that account for differences in the carcinogenic potencies of individual PAHs relative to that of B(a)P (USEPA 1994e). In this risk assessment, the oral SF for each carcinogenic PAH has been estimated by combining its RPF with the oral SF of B(a)P (see Table 4-3 in Section 4.3.3.2).

Animals exposed to high levels of B(a)P in air develop lung tumors; when exposed via the dietary route they develop stomach tumors; and when B(a)P is painted on skin, animals develop skin tumors. Although RfDs and SFs for dermal exposure to other chemicals are routinely extrapolated from oral-route values, it is inappropriate to use the oral SF of B(a)P to evaluate carcinogenic risks from dermal exposure, because direct dermal exposure to B(a)P directly causes skin cancer.

Polychlorinated Biphenyls (PCBs)

PCBs are a group of man-made chemicals composed of 209 individual compounds. They have been used widely in heat transfer fluids, lubricants, and dielectric materials in transformers, capacitors, and other electrical equipment because of their insulating and flame-resistant properties. The industrial manufacture of PCBs in the United States was stopped in 1977 in response to the discovery that PCBs could accumulate and persist in the environment and might cause adverse health effects. Although PCBs are no longer manufactured in the United States, people can be exposed to PCBs spilled or leaked from older transformers, capacitors, and other kinds of equipment, and to low levels of PCBs that are widespread throughout the environment. PCBs bind tightly to soils, and can be found in high concentrations in some freshwater and marine sediments. Some freshwater fish have bioconcentrated PCBs; eating fish from contaminated areas may be a potentially significant source of human exposure.

PCBs can enter the body when fish, other foods, or water containing PCBs are ingested, when air that contains PCBs is breathed, or when skin contact with PCBs occurs. Skin irritations characterized by acne-like lesions and rashes, and liver effects were the only significant adverse health effects reported in PCB-exposed workers. Epidemiological studies of workers occupationally exposed to PCBs thus far have not found any conclusive evidence of an increased incidence of cancer in these groups.

Effects of PCBs in experimentally exposed animals include liver damage, skin irritations, low birth weights and other reproductive effects, immunosuppression, and death. Some strains of rats and mice that were fed certain PCB mixtures throughout their lives showed increased incidence of cancer of the liver and other organs. Based on these animal studies, the EPA has classified PCBs as a Group B2, probable human carcinogen.

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Potassium

Potassium metal is soft and white with a silvery luster, has a low melting point, and is a good conductor of heat and electricity. Most potassium is present in minerals that are insoluble in water. There is little commercial demand for potassium metal itself, but it is used for preparing potassium superoxide and for alloying with sodium as a liquid metallic heat-transfer medium. In humans, potassium ions, together with sodium ions, act at cell membranes in transmitting electro-chemical impulses in nerve and muscle fibers and in balancing the activity of food intake and waste removal from cells (i.e., maintain intracellular fluid pressure and balance), therefore, too little or too much potassium in the body may be fatal. Symptoms of toxicity include muscular weakness and vomiting. If given intravenously, potassium can stop the heart. People's lives are not normally threatened by potassium overdoses as long as they are taken by mouth, because the presence of excess potassium in the stomach triggers a vomiting reflex that expels the unneeded substance.

Potassium is not classified by EPA as to its carcinogenic potential.

Selenium

Selenium is an essential trace element important in many biochemical and physiological processes including regulation of ion fluxes across membranes and stimulation of antibody synthesis. Selenium is found in all tissues of the body; highest concentrations occur in the kidney, liver, spleen, and pancreas. Recommended human dietary allowances (average daily intake) for selenium range from 10 to 15 µg for infants up to one year of age to 65 to 75 µg for pregnant or lactating women. There appears to be a relatively narrow range between levels of selenium intake that result in deficiency and those that cause toxicity.

Selenium occurs in several valence states and its toxicity varies with the valence state and water solubility of the compound in which it occurs. The water solubility of the compound may affect gastrointestinal absorption rates as well. Gastrointestinal absorption in animals and humans for various selenium compounds ranges from about 44 percent to 95 percent of the ingested dose.

In humans, acute oral exposures can result in excessive salivation, garlic odor to the breath, shallow breathing, diarrhea, pulmonary edema, and death. Other reported symptoms of acute selenosis include tachycardia, nausea, vomiting, abdominal pain, abnormal liver function, muscle aches and pains, irritability, chills, and tremors.

General signs and symptoms of chronic selenosis in humans include loss of hair and nails, acropachia (clubbing of the fingers), skin lesions (redness, swelling, blistering, and ulcerations), tooth decay (mottling, erosion, and pitting), and nervous system abnormalities attributed to polyneuritis (peripheral anesthesia, acroparaethesia, pain in the extremities, hyperreflexia of the tendon, numbness, convulsions, paralysis, motor disturbances, and hemiplegia). Evidence of teratogenicity in humans and laboratory animals is lacking. However, adverse reproductive and developmental effects (decreased rates of conception, increased rates

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of fetal resorption, and reduced fetal body weights) have been reported for domesticated and laboratory animals exposed to selenium.

In humans, inhalation of selenium or selenium compounds primarily affects the respiratory system. Dusts of elemental selenium and selenium dioxide can cause irritation of the skin and mucous membranes of the nose and throat, coughing, nosebleed, loss of sense of smell, dyspnea, bronchial spasms, bronchitis, and chemical pneumonia. Irritation and redness of the eyes, gastrointestinal distress (nausea and vomiting), depressed blood pressure, elevated pulse rate, headaches, dizziness, and malaise may also occur. Information on toxicity of selenium in humans following chronic inhalation exposures is not available.

Epidemiologic studies in humans have failed to show a positive association between chronic oral exposures to selenium and an increased incidence of death. In studies on laboratory animals, selenites or selenates have not been found to be carcinogenic. EPA has placed selenium and selenious acid in Group D, not classifiable as to carcinogenicity in humans.

Silver

Silver is a soft metal that occurs naturally in pure form and in ores. Silver compounds have been used industrially in the manufacture of photographic film, indelible inks, and medications. Photographic materials are the major source of silver released to the environment.

In general, silver in the environment binds to minerals in soil. However, silver can convert to forms that dissolve in water. Most people are exposed daily to very low levels of silver in food and water. It is less likely for the general public to be exposed to silver in air.

Most of the information about health effects caused by human exposure to silver is based on exposure to very high concentrations of silver in medications or the work place, such as chemical manufacturing facilities. Long-term oral or inhalation exposure to silver compounds can cause a gray or blue-gray color in some areas of skin or other body tissues. This condition, called argyria, is permanent but thought to be only a cosmetic problem.

Argyria is the critical or most sensitive health effect of exposure to silver. Other health effects seen in humans include minor allergic reactions from dermal exposure to silver and irritation of the throat, lungs, and stomach after exposure to dust containing high levels of silver compounds.

Studies of long-term exposure of laboratory animals to silver have demonstrated reduced activity, decreased weight gain, and enlarged hearts. It is not known whether similar effects could occur in humans, although some occupational studies in humans suggest silver can cause kidney problems.

There are no data regarding the carcinogenic potential of oral or inhalation exposure to silver in animals or humans.

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Sodium

Sodium, a soft, silvery-white metal, occurs abundantly in nature and is the most common alkali metal. The metal is extremely active chemically and is commercially produced by electrolyzing sodium chloride. Sodium is widely used in the manufacture of chemicals (particularly the lead alloy Na₄Pb, used in making tetraethyl lead) and has several pharmaceutical and metallurgical applications. It is also used as a heat exchange medium in atomic reactors and certain types of engines, and in sodium vapor lamps. Sodium, the principal extracellular ion, has the property of holding water in body tissues. Excessive levels of sodium in persons with circulatory problems may result in edema, or retention of water in the body. Too little sodium in the diet disturbs the tissue-water and acid-base balance that is important to maintain good nutritional status.

Toxicity symptoms of overexposure to sodium include hypertension. Sodium, in combination with other negative ions, apparently causes water retention and certain hormonal responses, but sodium chloride, uniquely, seems to raise blood pressure. Most people can safely consume more salt than they need and rely on control mechanisms (involving the kidneys, the adrenal glands, the pituitary gland, and other glands) to regulate its excretion and retention as needed. Sodium-sensitive individuals, however, experience high blood pressure from excesses in sodium or salt intake. People with chronic renal disease, those whose parents have hypertension, blacks, and persons over 50 years of age are most likely to be sodium (or salt) sensitive.

Sodium is not classified by EPA as to its carcinogenic potential.

Toluene

Toluene is used as a solvent in the production of a variety of products and as a constituent in the formulation of gasoline and aviation fuels. Toluene can enter and affect the body if it is inhaled, comes in contact with the eyes or skin, or is swallowed.

Exposure to toluene can cause many central nervous system effects. Toluene may cause fatigue, weakness, confusion, headache, dizziness, drowsiness, and irritation of the eyes, respiratory tract, and skin. These symptoms have been reported in association with occupational exposure to airborne concentrations of toluene ranging from 50 ppm (189 mg/m³) to 1,500 ppm (5,660 mg/m³). Symptoms generally increase in severity with increased exposures.

Toluene does not appear to cause cancer in animals or humans. No increased risk of cancer was detected in studies of occupationally exposed men. Similarly, toluene did not cause cancer in rats and mice exposed via inhalation.

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1,1,1-Trichloroethane (1,1,1-TCA)

1,1,1-TCA is a man-made chemical that has many industrial and household uses. For example, it is used as a cleaning solvent to remove oil or grease from manufactured metal parts, and as a solvent to dissolve other substances such as glue and paint. Consumer products such as spot removers may contain 1,1,1-TCA. Much of the 1,1,1-TCA produced in the United States ends up in the atmosphere as a result of evaporation during use. 1,1,1-TCA released onto or into the ground can migrate into groundwater.

Inhalation is the major route of exposure in humans, but humans can also be exposed by consuming contaminated food and water and by skin contact with 1,1,1-TCA contaminated soil and water. 1,1,1-TCA is readily absorbed into the body following exposure by inhalation or ingestion. It readily leaves the body with exhaled air.

Inhalation of high levels of 1,1,1-TCA for a short time by humans has resulted in CNS effects such as dizziness, lightheadedness, and loss of balance and coordination. These health effects are readily reversible when exposure stops. Studies in animals and humans have shown that mild liver effects result from long-term exposure. Kidney damage has also been reported in animal studies.

Cancer studies were performed on mice and rats dosed orally. No consistent pattern of an increased incidence of cancer was found, but the study was of limited value because of the death of many of the animals. It is not known whether 1,1,1-TCA causes cancer in humans.

Trichlorofluoromethane

Trichlorofluoromethane (Freon-11) is used in refrigeration machinery when a refrigerant effective at negative pressures is required and as an aerosol propellant. Though one of the most toxic fluorocarbons, it is less toxic than carbon dioxide, but decomposes into harmful materials when heated. It may be a narcotic at high concentrations, and there is evidence that it sensitizes dogs to epinephrine at a concentration of 0.3 percent; such an effect has also occurred in humans.

Trichlorofluoromethane is not classified by EPA as to its carcinogenic potential.

Vanadium

Vanadium is a naturally occurring grey metal. In the environment, vanadium is commonly found combined with other elements including oxygen and sulfur. Vanadium oxide is the compound of vanadium that is used most extensively by industry. The largest industrial use of vanadium oxide is in steel manufacturing, but it is also used in plastic, rubber, ceramic, and other chemical manufacturing.

Burning fuel oil and coal releases vanadium to the atmosphere. In water, vanadium is not very soluble, but is usually carried in surface water and groundwater in small particles.

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Because vanadium is naturally occurring, people are likely to be exposed to low concentrations of vanadium in food and drinking water. People are likely to be exposed to vanadium in air near industries that use vanadium, waste disposal areas of these industries, or downwind of fuel oil or coal burning areas. Once in the body, most vanadium is not absorbed from the respiratory or digestive tract. Vanadium is not believed to be absorbed through skin.

Humans exposed to large amounts of vanadium in air have experienced coughs, and eye and throat irritation. However, these effects stop soon after exposure stops. Long-term oral exposure of rats to vanadium causes minor cell changes in the kidney and lungs. Female rats exposed to vanadium have offspring of decreased body weights. It is unknown whether humans experience effects similar to vanadium-exposed rats.

There have been no specific studies of the carcinogenicity of vanadium. No increase of cancer has been noticed in studies of long-term oral exposure of rats, but these studies are less sensitive than specific cancer studies.

Zinc

Zinc is a naturally occurring element that can be found in a variety of compounds. Zinc has many industrial uses including galvanizing steel and manufacturing zinc-containing alloys such as brass. Zinc is an essential nutrient, and an inadequate amount of zinc in the diet will lead to adverse health effects.

People are exposed to low concentrations of zinc every day in air, water, soil, and food. Sources of zinc exposure include drinking water containing elevated levels of zinc and breathing air containing elevated levels of zinc from galvanizing, smelting, welding, or brass foundry operations. Drinking water is thought to be the most significant exposure route to zinc at hazardous waste sites.

Zinc appears to be toxic only at levels at least 10 times higher than the recommended daily allowance. Symptoms of overexposure may include severe diarrhea, stomach cramping, nausea, and vomiting. Serious damage to the digestive system can occur if too much zinc is ingested over a long period of time. Ingesting too much zinc can cause deficiency in other nutrients such as iron (anemia) and copper. Anemia is the critical effect or most sensitive effect caused by zinc overexposure. Inhalation of zinc fumes or dusts has been associated with a condition called "metal fume fever" characterized by flu-like symptoms including throat irritation, body aches, weakness, and fatigue.

Zinc is not thought to cause cancer or birth defects.

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4.3.3 Quantitative Indices of Toxicity

Quantitative indices of toxicity were compiled for the dose-response assessment to be used in estimating the relationship between the extent of exposure to a contaminant and the potential increased likelihood and/or severity of adverse effects. The methods for deriving indices of toxicity and estimating potential adverse effects are presented below. The indices of toxicity for the COPCs are presented at the end of this section.

4.3.3.1 Categorization of Chemicals as Carcinogens or Noncarcinogens

For the purpose of this risk assessment, COPCs were classified into two groups: potential carcinogens and noncarcinogens. The risks posed by these two types of compounds are assessed differently because noncarcinogens generally exhibit a threshold dose below which no adverse effects occur, while no such threshold has been shown to exist for carcinogens.

As used here, the term carcinogen means any chemical for which there is sufficient evidence that exposure may result in continuing uncontrolled cell division (cancer) in humans and/or animals. Conversely, the term noncarcinogen means any chemical for which the carcinogenic evidence is negative or insufficient. These classifications are dynamic; chemicals may be reclassified any time additional evidence becomes available that shifts the weight-of-evidence one way or the other.

COPCs have been classified as carcinogens or noncarcinogens based on weight-of-evidence criteria contained in the EPA carcinogenicity evaluation guidelines (USEPA 1986c). As mentioned earlier, Table 4-2 summarizes the five EPA weight-of-evidence categories. According to these EPA guidelines, chemicals in the first two groups--A and B (B1 or B2)--are considered human carcinogens or probable human carcinogens based on sufficient evidence and should be the subject of nonthreshold carcinogenic risk estimation procedures. Depending upon the quality of the data, Group C chemicals may also be subjected to these procedures. The remaining chemicals--in Groups D and E--are defined as noncarcinogens and should be subjected to threshold-based toxicological risk estimation procedures.

Exposure to some chemicals may result in both carcinogenic and noncarcinogenic effects. In these cases, both the carcinogenic and noncarcinogenic effects were evaluated and considered in the risk assessment process.

4.3.3.2 Assessment of Carcinogens

In contrast to noncarcinogenic effects for which thresholds are thought to exist, scientists have been unable to demonstrate experimentally a threshold for carcinogenic effects. This has led to the assumption by Federal regulatory agencies (e.g., EPA, Food and Drug Administration [FDA], and Occupational Safety and Health Administration [OSHA]) that any exposure to a carcinogen theoretically entails some finite risk of cancer. However, depending on the potency of a specific carcinogen and the level of exposure, such a risk could be vanishingly small.

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Scientists have developed several mathematical models to estimate low-dose carcinogenic risks from observed high-dose risks. Consistent with current theories of carcinogenesis, the EPA has selected the linearized multistage model based on prudent public health policy (USEPA 1986a). In addition to using the linearized multistage model, the EPA uses the upper 95th percentile confidence limit for doses or concentrations in animal or human studies to estimate low-dose SFs. By using these procedures, the regulatory agencies are unlikely to underestimate the actual SFs (formerly called carcinogenic potency factors) for humans.

Using SFs, lifetime excess cancer risks can be estimated by:

Risk =
$$\Sigma LADI_i \times SF_i$$

where

 $\begin{array}{lll} LADI_j &=& Exposure \ route-specific \ lifetime \ average \ daily \ intake \\ SF_j &=& Route-specific \ slope \ factor. \end{array}$

Using the multistage model, the carcinogenic risks for the oral and dermal routes of exposure are calculated as follows:

$$Risk = LADI_0SF_0 + LADI_dSF_0$$

where subscript "o" indicates the oral route and subscript "d" the dermal route.

SFs for the COPCs for the oral route are presented in Table 4-3. The EPA's weight-of-evidence classification for the chemical and the type of cancer that may be associated with exposure to the chemical are also included in Table 4-3. The preferred source for SFs is the EPA's Integrated Risk Information System (IRIS) data base (USEPA 1994), which contains confirmed values reflecting the consensus judgment of the agency. The second choice was the EPA's Health Effects Assessment Summary Tables (HEAST), which contain information taken from final documents prepared by the EPA Office of Health and Environmental Assessment (USEPA 1994c).

Currently there are no SFs in IRIS or HEAST for carcinogenic PAHs other than B(a)P. The SFs for carcinogenic PAHs in Table 4-3 have been estimated by multiplying the SF of B(a)P from IRIS by the RPFs recently adopted by EPA Region I (EPA 1994e).

4.3.3.3 Assessment of Noncarcinogens

Risks associated with noncarcinogenic effects (e.g., organ damage, immunological effects, birth defects, and skin irritation) are usually assessed by comparing the estimated average daily intake to the acceptable daily dose, now called the "reference dose" (RfD) by the EPA. The RfD is selected by identifying the lowest reliable no observed adverse effect

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i.		Table 4-3	4-3	
ORAL 1	L TOXICITY V.	ALUES FOR POTE	FOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS	IC EFFECTS
Chemical	Slope Factor (SF) (mg/kg/day)-1	Weight-of-Evidence Classification	Type of Cancer	SF Basis/SF Source
Arsenic	1.8	A	Skin	Drinking water/IRIS
Benzo(b)fluoranthene	7.3E-01	B2	NA	SF of B(a)P x RPF (0.1)/IRIS, RU
Beryllium	4.3	B2	Total tumors	Drinking water/IRIS
Bis(2-ethylhexyl)phthalate	1.4E-02	B2	Liver	Diet/IRIS
Butylbenzylphthalate	ND	С	Leukemia	NA/IRIS
Chlordane	1.3	B2	Liver	Diet/IRIS
Chrysene	7.3E-03	B2	NA	SF of B(a)P x RPF (0.001)/ IRIS, RU
P,P'-DDD	2.4E-01	B2	Liver, thyroid	Diet/IRIS
P,P'-DDE	3.4E-01	B2	Liver, thyroid	Diet/IRIS
P,P'-DDT	3.4E-01	B2	Liver	Diet/IRIS
Dieldrin	16	B2	Liver	Diet/IRIS
Heptachlor	4.5	B2	Liver	Diet/IRIS
Heptachlor epoxide	9.1	B2	Liver	Diet/IRIS
alpha-Hexachlorocyclohexane (alpha-BHC)	6.3	В2	Liver	Diet/IRIS
Lead	ND	· B2	NA	NA/IRIS
Methylene chloride	7.5E-03	B2	Liver	Drinking water/IRIS

Key at end of table.

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		Table 4-3	4-3	
ORA	L TOXICITY V.	ALUES FOR POTH	ORAL TOXICITY VALUES FOR POTENTIAL CARCINOGENIC EFFECTS	IC EFFECTS
Chemical	Slope Factor (SF) (mg/kg/day) ⁻¹	Weight-of-Evidence Classification	Type of Cancer	SF Basis/SF Source
4-Methylphenol (p-Cresol)	ND	C	NA	NA/IRIS
Polychlorinated biphenyls (PCBs)	7.7	B2	Liver	Diet/IRIS

Note: The following COPCs have not been assigned a carcinogenicity weight-of-evidence classification by the EPA: acenaphthene antimony, barium, calcium, chromium (III), cobalt, di-n-octylphthalate, endosulfan, iron, magnesium, 2-methylnaphthalene, potassium, sodium, trichlorofluoromethane, and vanadium. The following COPCs have been assigned to Group D (inadequate evidence of carcinogenicity) by the EPA: aluminum, 2-butanone, copper, din-butyl phthalate, endrin, fluoranthene, manganese, mercury, 2-nitrotoluene, phenanthrene, pyrene, selenium, silver, toluene, 1,1,1trichloroethane, and zinc.

The following COPCs are carcinogenic by the inhalation route only: cadmium (B1), chromium VI (A), and nickel (A).

Key:

HEAST = Health Effects Assessment Summary Tables.

IRIS = Integrated Risk Information System.

NA = Not applicable. ND = Not determined.

RPF = Relative Potency Factor.

RU = Risk Update number 2 (USEPA 1994e).

Source: Ecology and Environment, Inc. 1994.

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level (NOAEL) or lowest observed adverse effect level (LOAEL) in the scientific literature, then applying a suitable uncertainty factor (usually ranging from 10 to 1,000) to allow for differences between the study conditions and the human exposure situation to which the RfD is to be applied. NOAELs and LOAELs can be derived from either human epidemiological studies or animal studies; however, they are usually based on laboratory experiments on animals in which relatively high doses are used. Consequently, uncertainty or safety factors are applied when deriving RfDs to compensate for data limitations inherent in the underlying experiments and for the lack of precision created by extrapolating from high doses in animals to lower doses in humans. The application of uncertainty factors in the derivation of RfDs is explained in RAGS-HHEM (USEPA 1989) and outlined below.

The RfD is derived from the NOAEL (or LOAEL) for the critical toxic effect by consistent application of uncertainty factors (UFs) and a modifying factor (MF). The uncertainty factors generally are multiples of 10 (although values less than 10 are sometimes used), with each factor representing a specific area of uncertainty inherent in the extrapolation from the available data. The bases for application of different uncertainty factors are explained below.

- A UF of 10 is used to account for variation in the general population and is intended to protect sensitive subpopulations (e.g., elderly persons, children).
- A UF of 10 is used when extrapolating from animals to humans.
 This factor is intended to account for the interspecies variability between humans and other mammals.
- A UF of 10 is used when a NOAEL derived from a subchronic instead of a chronic study is used as the basis for a chronic RfD.
- A UF of 10 is used when a LOAEL is used instead of a NOAEL.
 This factor is intended to account for the uncertainty associated with extrapolating from LOAELs to NOAELs

In addition to the UFs listed above, a modifying factor (MF) is applied:

An MF ranging from greater than 0 to 10 is included to reflect a
qualitative professional assessment of additional uncertainties in the
critical study and in the entire data base for the chemical not
explicitly addressed by the preceding uncertainty factors. The default
value for the MF is 1.

To calculate the RfD, the appropriate NOAEL (or the LOAEL if a suitable NOAEL is not available) is divided by the product of all of the applicable uncertainty factors and the modifying factor. That is:

RfD = NOAEL or LOAEL/(UF₁ x UF₂... x MF)

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Oral RfDs are typically expressed as one significant figure in units of mg/kg-day.

The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a portion of the lifetime, in the case of a subchronic RfD, or during the entire lifetime, in the case of a chronic RfD. The RfD is used as a reference point for gauging the potential effects of other exposures. Usually, exposures that are less than the RfD are not likely to be associated with health risks. As the frequency of exposures exceeding the RfD increases and as the size of the excess increases, the probability increases that adverse health effects may be observed in a human population. Nonetheless, a clear distinction that would categorize all exposures below the RfD as "acceptable" (risk-free) and all exposures in excess of the RfD as "unacceptable" (causing adverse effects) cannot be made (USEPA 1993d). Noncarcinogenic risks are usually assessed by calculating a hazard quotient, which is the ratio of the estimated exposure to the RfD as follows:

$$HQ = \frac{ADI}{RfD}$$

where:

HQ = Hazard Quotient

ADI = Average Daily Intake (exposure)

RfD = Reference Dose (acceptable daily intake).

HQs that are associated with the same type of critical effect should be summed across pathways and chemicals to obtain a hazard index. A hazard index greater than 1.0 indicates that adverse effects may be possible while a value less than 1.0 means that adverse effects would not be expected. The higher the hazard index is above 1.0, the more likely it is that adverse effects could occur.

The EPA is in the process of developing subchronic RfDs based on potential noncarcinogenic effects associated with exposure durations ranging from a few weeks to seven years. Short-term exposures can occur when an activity resulting in exposure is performed for a limited period of time or when a chemical degrades or disperses to negligible concentrations within a short period. The hazard quotient for subchronic exposure is obtained by dividing the estimated average daily dose by the subchronic RfDs. Exposures of greater than 7 years duration (adult and adolescent exposures) were evaluated using chronic RfDs. Exposures of 7 years duration or less were evaluated using subchronic RfDs where available.

Chronic and subchronic RfDs for the oral exposure route are presented in Table 4-4. As with the SFs, the preferred source for RfDs was IRIS and the secondary source was HEAST. For some chemicals, following recommendations in the HEAST manual, RfDs were obtained from Environmental Criteria Assessment Office's (ECAO's) Superfund Health Risk Technical Support Center. Finally, the MDEP documentation for the Risk Assessment Short

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			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
æ	4	Reference Dose (Rfd)	0			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Acenaphthene	Chronic	6E-02	Low	Hepatotoxicity	Gavage/IRIS	UF = 3,000 MF = 1
	Subchronic	6E-01	NS	Hepatotoxicity	Gavage/HEAST	UF = 300
Antimony	Chronic	4E-04	Low	Reduced lifespan, altered blood chemistry	Drinking water/IRIS	UF = 1,000 MF = 1
	Subchronic	4E-04	NS	Reduced lifespan, altered blood chemistry	Drinking water/HEAST	UF = 1,000
Arsenic	Chronic	3E-04	Medium	Keratosis and hyperpigmentation	Oral/IRIS	UF = 3 $MF = 1$
	Subchronic	3E-04	NS	Keratosis and hyperpigmentation	Oral/HEAST	UF = 3
Barium	Chronic	7E-02	Medium	Increased blood pressure	Drinking water/IRIS	UF = 3 $MF = 1$
	Subchronic	7E-02	NS	Increased blood pressure	Drinking water/HEAST	UF = 3

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			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	IY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
	R	Reference Dose (Rfd))			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Benzo(b)fluoranthene	Chronic	4E-02	SN	NA	Extrapolated from naphthalene/	
	Subchronic	4E-02	NS	NA	Extrapolated from naphthalene/	
Beryllium	Chronic	5E-03	Low	None observed	Drinking water/IRIS	UF = 100 MF = 1
	Subchronic	5E-03	NS	None observed	Drinking water/HEAST	UF = 100
Bis(2-ethylhexyl)phthalate	Chronic	2E-02	Medium	Increased relative liver weight	Diet/IRIS	UF = 1,000 $MF = 1$
	Subchronic	2E-02	NS	Increased relative liver weight	Extrapolated from chronic	
Butylbenzylphthalate	Chronic	2E-01	Low	Increased liver weight	Diet/IRIS	UF = 1,000 $MF = 1$
	Subchronic	2E+00	NS	Altered liver weight	Diet/HEAST	UF = 100
2-Butanone	Chronic	6E-01	Low	Decreased birth weight	Diet/IRIS	UF = 3,000 $MF = 1$

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			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	TY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
	24	Reference Dose (Rfd)	0			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
	Subchronic	2E+00	NS	Decreased birth weight	Drinking water/HEAST	UF = 1,000
Cadmium	Chronic (drinking water)	5E-04	High	Significant proteinuria	Drinking water/IRIS	UF = 10 $MF = 1$
	Subchronic (drinking water)	5E-04	NS	Significant proteinuria	Extrapolated from chronic	
Cadmium	Chronic (diet)	1E-03	High	Significant proteinuria	Diet/IRIS	UF = 10 $MF = 1$
	Subchronic (diet)	1E-03	NS	Significant proteinuria	Extrapolated from chronic	
Chlordane	Chronic	6E-05	Low	Liver hypertrophy	Diet/IRIS	UF = 1,000 $MF = 1$
	Subchronic	6E-05	NS	Liver hypertrophy	Diet/HEAST	UF = 1,000
Chromium (VI)	Chronic	5E-03	Low	None reported	Drinking water/IRIS	UF = 500 $MF = 1$
	Subchronic	2E-02	NS	None observed	Drinking water/HEAST	UF = 100

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,			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
	~	Reference Dose (Rfd)	(1			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Chromium (III)	Chronic	1E+00	Low	None observed	Diet/IRIS	UF = 100 $MF = 10$
	Subchronic	1E+00	NS	None observed	Diet/HEAST	UF = 1,000
Chrysene	Chronic	4E-02	NS	NA	Extrapolated from naphthalene/	,
	Subchronic	4E-02	NS	NA	Extrapolated from naphthalene/	
Copper	Chronic	3.7E-02	NS	Local GI Irritation	Derived from drinking water standard/ HEAST	
	Subchronic	3.7E-02	NS	Local GI Irritation	Derived from drinking water standard/ HEAST	
p,p'-DDT	Chronic	5E-04	Medium	Liver lesions	Diet/IRIS	UF = 100 $MF = 1$
	Subchronic	5E-04	NS	Liver lesions	Diet/HEAST	UF = 100

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			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
	4	Reference Dose (Rfd)	(1			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Di-n-butylphthalate	Chronic	1E-01	Low	Increased mortality	Diet/IRIS	UF = 1,000 MF = 1
	·Subchronic	1E+00	NS	Increased mortality	Diet/HEAST	UF = 100
Dieldrin	Chronic	5E-05	Low	Liver lesions	Diet/IRIS	UF = 100 $MF = 1$
	Subchronic	SE-05	NS	Liver lesions	Diet/HEAST	UF = 100
Di-n-octylphthalate	Chronic	2E-02	NS SN	Increased liver and kidney weight	Diet/HEAST	UF = 1,000
× .	Subchronic	2E-02	NS	Increased liver and kidney weight	Diet/HEAST	UF = 1,000
Endosulfan	Chronic	6E-03	NS	Decreased weight gain, kidney toxicity, aneurisms	Diet/HEAST	UF = 100
	Subchronic	6E-03	NS	Decreased weight gain, kidney toxicity, aneurisms	Diet/HEAST	UF = 100

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			Table 4-4			
	TOXICITY	VALUES FOR F	POTENTIAL NO	IY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
	2	Reference Dose (Rfd)				
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Endrin	Chronic	3E-04	Medium	Liver lesions, convulsions	Diet/IRIS	UF = 100 $MF = 1$
	Subchronic	3E-04	NS	Liver lesions, convulsions	Diet/HEAST	UF = 100
Fluoranthene	Chronic	4E-02	Low	Nephropathy; liver weight changes; hematological changes	Gavage/IRIS	UF = 3,000 MF = 1
, .	Subchronic	4E-01	NS	Nephropathy; liver weight changes; hematological changes	Gavage/HEAST	UF = 300
Heptachlor	Chronic	5E-04	Low	Increased liver weight	Diet/IRIS	UF = 300 MF = 1
4	Subchronic	5E-04	NS	Increased liver weight	Diet/HEAST	UF = 300
Heptachlor epoxide	Chronic	1.3E-05	Low	Increased liver weight	Diet/IRIS	UF = 1,000 $MF - 1$
,	Subchronic	1.3E-05	NS	Increased liver weight	Diet/HEAST	UF = 1,000

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	Œ		Table 4-4			
	TOXICITY	VALUES FOR P	OTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	C EFFECTS	
	R	Reference Dose (Rfd)	(
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
Manganese	Chronic (drinking water)	5E-03	Varied	CNS effects	Drinking water/IRIS	UF = 1 $MF = 1$
	Subchronic (drinking water)	5E-03	NS	CNS effects	Drinking water/HEAST	UF = 1
×	Chronic (food)	1.4E-01	Varied	CNS effects	Diet/IRIS	UF = 1 $MF = 1$
	Subchronic (food)	1.4E-01	NS	CNS effects	Diet/HEAST	UF = 1
Mercury (inorganic)	Chronic	3E-04	NS	Kidney effects	Oral/HEAST	UF = 1,000
	Subchronic	3E-04	NS	Kidney effects	Oral/HEAST	UF = 1,000
Methylene chloride	Chronic	6E-02	Medium	Liver toxicity	Drinking water/IRIS	UF = 100 $MF = 1$
•	Subchronic	6E-02	NS	Liver toxicity	Drinking water/HEAST	UF = 100

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			Uncertainty (UF) and Modifying (MF) Factors		-	UF = 300 $MF = 1$	UF = 300	UF = 10,000 $MF = 1,000$		У.	
	IC EFFECTS		RfD Basis/ Source	Extrapolated from naphthalene/MDEPRS	Extrapolated from naphthalene/MDEPRS	Diet/IRIS	Diet/HEAST	Gavage/HEAST	Gavage/HEAST	Extrapolated from naphthalene/MDEPRS	Extrapolated from naphthalene/MDEPRS
	ITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS		Critical Effects	NA	NA	Decreased body and organ weight	Decreased body and organ weight	Spleen lesions	Spleen lesions	NA	NA
Table 4-4	POTENTIAL NO	1)	Confidence Level	NS	NS	Medium	NS	NS	NS	NS	NS
	VALUES FOR 1	Reference Dose (Rfd)	Value mg/kg/day	4E-02	4E-02	2E-02	2E-02	1E-02	1E-01	4E-02	4E-02
	TOXICITY		Type	Chronic	Subchronic	Chronic	Subchronic	Chronic	Subchronic	Chronic	Subchronic
9			Chemical	2-Methylnaphthalene		Nickel		2-Nitrotoluene		Phenanthrene	

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			Table 4-4			
	TOXICITY	VALUES FOR I	POTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	IC EFFECTS	
٠	2	Reference Dose (Rfd)	()			
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
PCB 1254	Chronic	2E-05	Medium	Ocular exudate, inflamed and prominent meibomion glands	Diet/IRIS	
	Subchronic	2E-05	NS	N/A	Extrapolated from chronic	
Pyrene	Chronic	3E-02	Low	Kidney effects	Gavage/IRIS	UF = 3,000 $MF = 1$
	Subchronic	3E-01	NS	Kidney effects	Gavage/HEAST	UF = 300
Selenium	Chronic	5E-03	High	Selenosis	Diet/IRIS	UF = 3 $MF = 1$
	Subchronic	5E-03	NS	Selenosis	Diet/HEAST	UF = 3
Silver	Chronic	5E-03	Low	Argyria	Diet/IRIS	UF = 3 $MF = 1$
	Subchronic	5E-03	NS	Argyria	Diet/HEAST	UF = 3
Toluene	Chronic	2E-01	Medium	Changes in liver and kidney weights	Gavage/IRIS	UF = 1,000 $MF = 1$
*	Subchronic	2E+00	NS	Changes in liver and kidney weights	Gavage/HEAST	UF = 100

Key at end of table.

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			Table 4-4			
	TOXICITY	VALUES FOR P	OTENTIAL NO	TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS	C EFFECTS	
	R	Reference Dose (Rfd)				
Chemical	Type	Value mg/kg/day	Confidence Level	Critical Effects	RfD Basis/ Source	Uncertainty (UF) and Modifying (MF) Factors
1,1,1-Trichloroethane	Chronic	9E-02	Medium	Hepatotoxicity	Oral/IRIS (withdrawn), MDEPRS	UF = 1,000 MF - 1
	Subchronic	9E-01	NS	Hepatotoxicity	Oral/IRIS (withdrawn), MDEPRS	UF = 100
Trichlorofluoromethane	Chronic	3E-01	Medium	Increased mortality, histopathology	Gavage/IRIS	UF = 1,000 $MF = 1$
	Subchronic	7E-01	NS	Increased mortality	Oral/HEAST	UF = 1,000
Vanadium	Chronic	7E-03	NS	None observed	Drinking water/HEAST	UF = 100
	Subchronic	7E-03	NS	None observed	Drinking water/HEAST	UF = 100
Zinc	Chronic	3E-01	Medium	Decrease in ESOD concentration	Diet/IRIS	UF = 3 $MF = 1$
	Subchronic	3E-01	NS	Decrease in ESOD concentration	Extrapolated from chronic	

Key at end of table.
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Table 4-4 (Cont.)

Note: RfDs could not be found for the following COPCs: aluminum, calcium, cobalt, p,p'-DDD, p,p'-DDE, alpha-hexachlorocyclohexane, iron, lead, magnesium, potassium, sodium.

Key:

= Central nervous system. CNS

Erythrocyte superoxide dismutase. ESOD

= Health Effects Assessment Summary Tables. HEAST

= Integrated Risk Information System. IRIS

= Massachusetts Department of Environmental Protection Residential Shortform (MDEP 1992). **MDEPRS**

Not applicable. Not specified.

V

Source: Ecology and Environment, Inc. 1994.

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Form (MDEP 1992) was consulted for additional RfDs that could not be found in the sources listed above.

Other entries in the table that have not been discussed previously are as follows: The confidence level indicates the degree of confidence that should be placed in the RfD value and is usually obtained from the IRIS entry for a chemical; the critical effect is the effect or target organ affected by the smallest dose of the chemical that produces any adverse effect and that serves as the basis for the RfD; and the RfD source is the source or reference for the RfD.

4.3.3.4 Route-to-Route Extrapolation of Reference Doses and Slope Factors

Once substances have been absorbed via the oral or dermal routes, their distribution, metabolism, and elimination patterns (biokinetics) are usually similar. For this reason, and because dermal route RfDs and SFs are usually not available, oral route RfDs and SFs are commonly used to evaluate exposures to substances by both the oral and dermal routes. When this is done, the dermal intake is adjusted to account for differences in a chemical's absorption between the oral and dermal routes of exposure.

Extrapolation of toxicological indices from one route to another is inappropriate and is not done if the critical effect for either route is at the point of contact. For example, ingestion of carcinogenic PAHs (cPAHs) causes stomach cancer whereas dermal exposure causes skin cancer; therefore, the oral SF for benzo(a)pyrene, which is used to assess risks from oral exposures to cPAHs should not be used to estimate dermal risks.

4.3.3.5 Assessment of Chromium

Most metals can exist in the environment in more than one oxidation state; however, the analytical methods used in this investigation do not distinguish between the various forms. Generally, this is not an issue when assessing risks associated with most metals because a single toxicity value (or set of values) is used for each metal regardless of the oxidation state. However, the two major forms of chromium, hexavalent (Cr[VI]) and trivalent (Cr[III]), have different potential adverse health effects and different toxicological indices; Cr(VI) is considered to be much more toxic than Cr(III). Therefore, some assumptions must be made regarding the form of chromium present in each environmental medium of concern.

Most chromium in soil and sediment occurs as Cr(III); whereas Cr(VI) compounds, which are much more soluble than Cr(III) forms, generally predominate in surface water and groundwater, though Cr(III) associated with suspended sediment may also be present (USEPA 1984). For the human health risk assessments, the following conservative (health-protective) assumptions have been used:

- All chromium detected in water is assumed to be Cr(VI); and
- In soil and sediment, 10 percent of the chromium detected is assumed to be Cr(VI) and the remaining 90 percent Cr(III).

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4.3.3.6 Assessment of Lead

There are no verified or EPA consensus toxicological indices available for lead in either IRIS or HEAST. The absence of authoritative toxicological indices reflects the scientific community's inability to agree on a threshold dose for lead's noncarcinogenic effects or to satisfactorily estimate its carcinogenic potency, despite a large body of scientific literature on its toxicological effects (USEPA 1992e).

Young children are regarded as the segment of the population at greatest risk from lead exposure because in comparison to adults, their intake of lead from the gastrointestinal (GI) tract is greater (50% from children versus 6% for adults), and their developing organ systems are more sensitive to the toxic effects of lead. Initially, the EPA Office of Solid Waste and Emergency Response (OSWER) concluded that cleanup of lead in soil at Superfund sites to concentrations of 500 to 1,000 mg/kg was adequately protective for direct contact of children at residential settings, and issued a directive to that effect (USEPA 1989j); OSWER later revised this directive (USEPA 1991b) to recommend the use of an integrated lead uptake/biokinetic model (UBK), which predicts blood lead levels in children from their total exposure to lead in soil and other media, to determine site-specific soil cleanup levels; using default parameters, the UBK model predicted an acceptable soil lead level of approximately 500 ppm. In its most recent revised interim soil lead guidance (USEPA 1994b), OSWER recommends (based on application of the current version of the UBK model) a screening level of 400 ppm for lead in soil for residential land use. Generally, residential soils with lead levels below 400 ppm require no further action. In the human health risk assessment, risks from lead in soil and sediment are evaluated by comparing the concentrations found to the OSWER screening level.

In its National Primary Drinking Water Regulations, EPA has established a healthbased action level of 15 µg/L for lead in drinking water. This action level is expected to protect young children from most significant adverse effects from lead. Since the greatest exposure to lead in groundwater is likely to result from using the groundwater as drinking water, the action level is an appropriate screening criterion for evaluating its potential human health risks.

4.4 EXPOSURE ASSESSMENT PROCESS

There are three steps to the exposure assessment process: characterization of the exposure setting, identification of potential exposure pathways, and quantification of exposure. This section provides general information relevant to the exposure assessments for the RI sites and explains the process used to obtain quantitative exposure estimates. More detailed, site-specific information and the quantitative exposure assessments are presented in the risk assessments for the individual sites.

4.4.1 Characterization of the Exposure Setting

The first step of the exposure assessment is to characterize the exposure setting with respect to the physical setting of the site and the potentially exposed populations.

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4.4.1.1 Physical Setting

The physical setting of the Annex including geology, hydrogeology, climate, and current land used are described in Section 1.

4.4.1.2 Potentially Exposed Populations

Under current site conditions, potentially exposed populations include those groups who might enter contaminated areas on or near the sites. Because both RI sites are currently inactive, authorized entry is limited mainly to occasional visits by the security guards on patrol and possibly Fort Devens maintenance workers. Although some other areas of the Annex are currently used for testing, training, and authorized recreational purposes, and participants in these activities might occasionally pass through or near a site when entering or leaving adjacent areas, such exposures are likely to be infrequent and of very short duration.

Potentially exposed populations could also include site visitors who trespass into the Annex, possibly entering the RI sites. Although unauthorized entry into the Annex is limited by perimeter fences, road barriers, and periodic security patrols, trespassing commonly occurs, especially along the Annex boundaries near surrounding residential areas. Poachers hunt grouse, deer, and other game within the Annex. Adults and adolescents use the Annex for walks, dirt-biking, and other recreational activities. There is evidence of routine trespassing (graffiti, trash, sighting of trespassers, etc.) at site A12/P36/P37 which is located approximately 1,000 feet from an Annex entry point and the nearest off-site residences.

Current land use around the Sudbury Annex is mainly residential interspersed with light industry or agricultural areas. All or most of the Annex will eventually be released by the Army for public use; a few small areas that have already been excessed are now used recreationally (for dirt-biking, etc.). Future land use of the Annex property could include any of these possibilities.

4.4.2 Potential Exposure Pathways

A schematic depiction of the potential exposure pathways for the Annex, a generalized conceptual site model, is presented in Figure 4-1. Below is a general discussion.

4.4.2.1 Sources and Receiving Media

Past site activities and storage practices have contaminated soils in some areas of the Annex with elevated levels of some metals, pesticides, and PCBs. Semivolatile organic chemicals and traces of VOCs have also been found.

4.4.2.2 Contaminant Fate and Transport

The fate and transport of contaminants in the environment are influenced by a variety of site- and chemical-specific factors. Environmental fate and transport processes for the contaminants detected at the RI sites are summarized briefly in this section.

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Metals are persistent in the environment, but their chemical and physical forms can change depending on environmental conditions. Metals in soils and sediment may be in a metallic form, as oxides or other inorganic compounds, sorbed or chelated by organic matter or oxides, sorbed on exchange sites of soil colloids, or dissolved in soil water. Metals that normally exist in the environment in cationic forms, such as cadmium, copper, chromium (III), lead, nickel, and zinc, tend to form insoluble salts or bind to soil minerals and are relatively immobile in the subsurface at usual soil pH ranges and become leachable only if acidic solutions percolate through the soils. At the normal range of soil pH values, these metals usually do not leach at an appreciable rate. Metals that form acid anions such as arsenic, chromium (VI), molybdenum, selenium, and vanadium tend to be more water soluble and more mobile. Other environmental factors that influence metal mobility include soil clay content, organic content, oxidation-reduction potential, carbonate content, and groundwater chemistry.

Speciation of metals is also an important factor in their mobility. If the metals are present as oxides or hydroxides, they will remain relatively immobile in soils and sediments. If they are present as soluble salts, the most likely reaction that may occur is the hydrolysis of metals to either oxides or hydroxides, or the precipitation of low solubility sulfates or carbonates. Some metals, such as arsenic, cadmium, and mercury can bioconcentrate in aquatic organisms.

PCBs and pesticides, which have low water solubilities and a tendency to adsorb to soils, are relatively immobile in the subsurface. Some of these chemicals are persistent in the environment and may bioaccumulate in aquatic environments.

The semivolatile contaminants, primarily PAHs and phthalates, also have low solubilities and a tendency to adsorb to soil; therefore, these chemicals are also relatively immobile. Bioconcentration of some of these chemicals have been observed in aquatic and terrestrial organisms; however, this is limited by metabolism so that biomagnification through the food chain is unlikely.

VOCs, which have moderate to high vapor pressures, high water solubility, and little tendency for adsorption by soil and sediments, are highly mobile in the environment. At the surface, VOCs can volatilize to the atmosphere; in the subsurface, they can migrate downward with infiltrating precipitation, eventually reaching groundwater. Not surprisingly, only trace levels were found in environmental media in the study areas. Most organic contaminants undergo biotransformation or biodegradation in soil or groundwater when environmental conditions are favorable.

Migration by erosion of site soils is limited by pavement, structures, and vegetative cover; however, in periods of heavy rain even relatively immobile contaminants bound to surface soil can potentially migrate with surface runoff to lower elevations, possibly reaching nearby surface water bodies.

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4.4.2.3 Complete Exposure Pathways

As shown in Figure 4-1, the following exposure pathways are potentially complete under existing site conditions:

- Direct contact (dermal contact and incidental ingestion) with contaminated surface soil by site visitors; and
- Direct contact with contaminated sediment and surface water downgradient from sites by site visitors.

The same potential exposure pathways are expected to exist under future site conditions if the site is converted to residential use. However, future construction of homes could involve extensive soil excavation which would bring subsurface soils to the surface. Therefore, future site residents, as well as construction workers, could potentially be exposed to both surface and subsurface soil contamination.

Groundwater is not currently used as a water supply source at either site, and it is unlikely that future residents would use site groundwater because there are existing public water supply systems. However, if private wells were installed on site, future residents could be exposed to groundwater contaminants through household use.

The exposure pathways described above apply to both site P11/P13 and to site A12/P36/P37. Most were evaluated quantitatively in the site-specific human health risk assessments presented in Volumes II and III.

4.4.3 Quantification of Exposure

This section describes how the quantitative exposure estimates were obtained. The first part describes how the exposure point contaminant concentrations used in the exposure assessment calculations were selected or derived, and the second part describes the exposure estimation calculations for each receptor and route of exposure.

4.4.3.1 Exposure Point Concentrations

The exposure media of potential concern at the Annex include groundwater, soil, sediment, and surface water. For all of these media, the average chemical concentrations and the maximum observed concentrations from the relevant RI and SI data were used as estimates of exposure point concentrations for the average exposure and reasonable maximum exposure (RME) cases in accordance with EPA Region I guidance. For calculating an average concentration for a set of samples that included nondetects, a value equal to one-half the quantitation limit was used for nondetects unless that value exceeded the highest observed concentration. In cases where one-half the quantitation limit exceeded the highest observed concentration, the sample result was omitted from the calculation.

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See the site-specific risk assessments for details on the exposure media that were evaluated, and the samples and methods that were used to estimate exposure point concentrations.

4.4.3.2 Exposure Estimation Calculations

For each site, one or more exposure scenarios were selected for the quantitative risk assessment. A scenario is a combination of pathways by which an individual receptor or group of receptors might be exposed under a given set of conditions. Generally, the scenarios selected for quantitative assessment are those that are most likely to result in significant health risks. Exposure estimates for these scenarios are derived by combining the following:

- Estimates of exposure media concentrations, which were described in the previous section;
- Estimates of contact rate and the frequency and duration of exposure that the receptor population is likely to experience; and
- Estimates of various physiological parameters (e.g., breathing rate, body weight, and average life expectancy).

Two cases were evaluated for each exposure route and receptor to satisfy current EPA Region I requirements. In accordance with Region I guidance (USEPA 1989c), the RME case uses the highest observed contaminant concentrations and the average case uses the average concentration in the exposure media. Where appropriate, standard default exposure factors from EPA's Supplemental Risk Assessment Guidance for Superfund (USEPA 1991a) or other EPA guidance were used. In the absence of appropriate guidance values, exposure factors were taken from EPA's Exposure Factor's Handbook (USEPA 1989h) or were estimated from site-specific information using professional judgment.

See the site-specific risk assessments for the exposure equations used, the exposure factors selected, and the rationale for their selection.

The estimates from the exposure equations are expressed as chronic daily intakes (CDIs), subchronic daily intakes (SDIs), or lifetime average daily intakes (LADIs) for each complete pathway and exposure case. CDIs and SDIs are used to estimate noncarcinogenic risks. CDIs are calculated for exposure durations greater than 7 years, while SDIs are calculated for exposure durations less than 7 years. LADIs are used to estimate excess lifetime cancer risks. The exposure estimates are combined with toxicity estimates for each chemical (listed in Tables 4-3 and 4-4) to obtain risk estimates.

4.5 RISK CHARACTERIZATION

This section combines the information developed in the exposure and toxicity sections to obtain estimates of the potential risks posed by site-related contaminants to human health. The process by which this is done is explained below.

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4.5.1 Carcinogenic Risks

Potential carcinogenic risk is assessed by multiplying the estimated LADI of a carcinogen by its estimated SF to obtain the estimated risk, expressed as a probability of that exposure resulting in an excess incidence of cancer (i.e., more cancers than would normally be expected in that population). The excess cancer risk for exposure to each chemical by each route of exposure, category of receptor, and exposure case is initially estimated separately. The risk estimates are then summed across chemicals and across all exposure routes and pathways applicable to the same population to obtain the total cancer risk for that population.

Current EPA Superfund policy, as stated in the National Oil and Hazardous Substances Pollution Contingency Plan (USEPA 1992b), is that acceptable exposures to known or suspected carcinogens are generally those that represent an excess upper-bound lifetime cancer risk to an individual of between 10⁻⁴ and 10⁻⁶. In addition, the EPA uses the 10⁻⁶ risk level as the point of departure for determining remediation goals for NPL sites (USEPA 1992b).

4.5.2 Noncarcinogenic Risks

The potential for adverse effects resulting from exposure to systemic toxicants (noncarcinogens) is assessed by comparing the estimated CDI or SDI of a substance to its chronic or subchronic RfD. This comparison is performed by calculating the ratio of the CDI or SDI to its corresponding RfD, which is the hazard quotient (HQ). HQs should be summed across chemicals that produce the same type of adverse effects (e.g., liver damage), but should be kept separate if their critical effects are different. However, for screening purposes, HQs are commonly summed across all chemicals, exposure routes, and pathways applicable to a given population to obtain a hazard index (HI) for that population.

For noncarcinogens, the EPA defines acceptable exposure levels as those to which the human population, including sensitive subgroups may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety (USEPA 1992c). This acceptable exposure level is approximately an HI of 1.0. If the HI is less than 1.0, adverse effects usually would not be expected. As the HI increases beyond 1.0, the possibility of adverse effects occurring also increases.

4.5.3 Risk Estimates

Detailed tables containing estimates of potential exposures and associated risks for the study areas can be found in Appendix O. A directory has been included for each area to assist the reader in locating the exposure and risk estimates for specific exposure pathways, cases, and receptors.

The risk estimates are summarized and discussed in the site-specific risk characterizations in Volumes II and III. Each risk characterization also includes a review of the pathways

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and chemicals most likely to pose significant risks, and the nature of the potential adverse health effects.

4.6 RISK CHARACTERIZATION UNCERTAINTIES

The risk characterization combines and integrates the information developed in the exposure and toxicity assessments; therefore, uncertainties associated with these assessments also affect the degree of confidence that can be placed in risk characterization results. Toxicity assessment uncertainties and exposure assessment uncertainties are described below in Sections 4.6.1 and 4.6.2, respectively. Additional uncertainties, including those that result from the risk assessment process itself, are described in Section 4.6.3.

4.6.1 Uncertainties Related to the Toxicity Assessment

Due to the number of assumptions, data points, and calculations used to derive toxicity indices, a degree of uncertainty is necessarily associated with the numerical toxicity values in any risk assessment. To evaluate the meaning of any risk assessment, one must consider the uncertainties in the assumptions made, the potential impact of quantitative changes in those assumptions on the risk estimates, and the relevance of the findings to real world exposures and risks.

4.6.1.1 Evaluation of Carcinogenic Toxicity Assessment Assumptions

The COPCs have been evaluated by the EPA using its weight-of-evidence carcinogenicity evaluation criteria and have been placed in Group A, human carcinogens, or Group B, probable human carcinogens, based on sufficient data in humans or sufficient data in animals and insufficient data in humans, respectively (USEPA 1986c).

Rodent bioassay and epidemiological studies would require tens of thousands of animals or humans to determine whether a chemical may be carcinogenic at low doses. As the relationship between tumor location, time to appearance, and the proportion of animals with cancer determines the estimated carcinogenic SF, animal bioassay or human epidemiological data are not routinely sufficient for directly estimating SFs at low doses. Therefore, by necessity, agencies such as EPA use models to extrapolate low-dose SFs from the results of higher level exposures. The agencies also assume, based on prudent public policy, that no threshold exposure level exists for carcinogenic effects. In other words, every dose above zero, no matter how low, carries with it a small but finite risk of cancer. They also assume that the dose-response relationship is linear at low doses. This is contrary to approaches used for other toxic effects, for which thresholds are assumed to exist.

The current model favored by the EPA and certain other Federal regulatory agencies is the linearized multistage model. The EPA then uses the statistically derived upper 95 percent confidence limit for the slope, rather than a maximum likelihood value, for the SF. The EPA has concluded, based on theoretical grounds consistent with human epidemiological and animal data, that cancer follows a series of discrete stages (i.e., initiation, promotion, and progression) that ultimately can result in the uncontrolled cell proliferation known as cancer.

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Consistent with this conclusion, the use of the linearized multistage model permits an estimation of SF that is not likely to be exceeded if the real slope could be measured. However, compelling scientific arguments can be made for several other extrapolative models which, if used, could result in significantly lower SFs, than those estimated using the linearized multistage model. One such model is the one-hit model, which is used to estimate risks due to exposures above the linear range of the multistage model. Thus, the current EPA SFs calculated in this fashion represent upper-bound values that are usually based on animal data and should not be interpreted as necessarily equivalent to actual human cancer potencies. It is this conservative value, nevertheless, that is used in this risk assessment on policy grounds for the protection of public health.

4.6.1.2 Evaluation of Noncarcinogenic Toxicity Assessment Assumptions

Key assumptions used in assessing the likelihood of noncarcinogenic effects are that threshold doses exist below which various noncarcinogenic effects do not occur and that the occurrence or absence of noncarcinogenic effects can be extrapolated between species and occasionally between routes of exposure and over varying exposure durations. The threshold assumption appears to be sound for most noncarcinogens based on experimental data as compared to the usual dose response curves. One possible exception to this is lead, which may not have a threshold base for its noncarcinogenic effects (ATSDR 1993).

The other assumptions generally appear to be true to varying degrees. The effects observed in one species or by one route of exposure may not occur in another species or by another route, or they may occur at a higher or lower dose due to differences in the biokinetics of a compound in different species or when exposure occurs by different routes. The uncertainty in these assumptions is taken into account in the development of RfDs through the use of safety or uncertainty factors. These factors reflect uncertainty associated with speciesto-species extrapolation and include safety factors to protect sensitive individuals. In addition to uncertainty factors, a modifying factor is applied to reflect a qualitative professional assessment of additional uncertainties in the critical study and in the entire data base for the chemical not explicitly addressed by the preceding uncertainty factors. The modifying factor ranges from greater than 0 to 10 with a default value of 1 (USEPA 1989c).

The uncertainty factors and modifying factors used by the EPA are conservative (health protective) in nature in that they tend to overestimate the uncertainties so that the RfDs obtained are unlikely to be too high. Use of the resulting RfDs tends to overestimate the potential for noncarcinogenic effects occurring at a given exposure level. Section 4.3.3.3 discusses uncertainty factors used to derive the RfDs for COPCs at the Annex.

4.6.1.3 Route-to-Route Extrapolation of Reference Doses and Slope Factors

Route-to-route extrapolation of RfDs and SFs adds another source of uncertainty to the risk estimates obtained through their use. Such extrapolation may result in either underor overestimation of the true risks for the extrapolated route. Although this practice adds uncertainty to the risk assessment process, it appears to be preferable to omitting exposure to a chemical by a route for which no RfD or SF is available from the quantitative risk

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assessment, which would increase the possibility of underestimation of the overall risks posed by the chemical.

4.6.1.4 Chemicals Lacking Toxicological Indices

A number of chemicals identified as COPCs at the Sudbury Annex could not be carried through the quantitative risk estimation process due to the absence of quantitative toxicity indices (RfDs or SFs). The chemicals (aluminum, calcium, cobalt, iron, magnesium, potassium, and sodium) are all common constituents of soil and sediment. These metals, which can be taken up by plants, are also naturally present in many foods. Although some adverse health effects may be associated with high doses of some of these chemicals, under normal circumstances, these substances are considered to have low toxicity in humans; in fact, some are essential nutrients. Potential adverse health effects from exposures to these chemicals in site soil or groundwater are probably insignificant in comparison to the potential risks from more toxic COPCs that were carried through the quantitative assessment process.

4.6.1.5 Summary of Toxicity Assessment Uncertainties

The basic uncertainties underlying the assessment of the toxicity of a chemical include:

- Uncertainties arising from the design, execution, or relevance of the scientific studies that form the basis of the assessment;
- Uncertainties involved in extrapolating from the underlying scientific studies to the exposure situation being evaluated, including variable responses to chemical exposures within human and animal populations, between species, and between routes of exposure; and
- The absence of quantitative toxicological indices for some COPCs may result in a slight underestimation of the total risks posed by the site.

These basic uncertainties could result in a toxicity estimate, based directly on the underlying studies, that either underestimates or overestimates the true toxicity of a chemical in the circumstances of interest.

The toxicity assessment process compensates for these basic uncertainties through the use of safety factors (uncertainty factors) and modifying factors when assessing noncarcinogens, and the use of the upper 95 percent confidence limit from the linearized multistage model for the SF when assessing carcinogens. The use of the safety factors and the upper 95 percent confidence limit in deriving the RfDs and SFs ensures that the toxicity values used in the risk estimation process are very unlikely to underestimate the true toxicity of a chemical.

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4.6.2 Uncertainty in the Exposure Assessment

A number of factors will cause the estimated exposure levels to differ from the exposures that potential receptor populations may actually experience. This section will identify these factors, discuss the potential effects of the factors on the exposure estimates and, where possible and appropriate, estimate the degree of confidence that should be placed in the various assumptions and parameter estimates that have gone into the exposure estimates.

4.6.2.1 Environmental Sampling

Samples collected during the RI were intended to characterize the nature and extent of contamination at each site. Accordingly, most were collected from locations selected in a purposeful or directed manner to accomplish this goal. Samples collected in this manner provide considerable information about each site but are not statistically representative of the contamination that may be present on the site as a whole. In order to gather statistically representative data, the sampling locations need to be selected in a random or systematic fashion, usually using a grid system.

While the data are not statistically representative, there is no reason to believe that they are not typical for the areas sampled. Development of the source media concentrations used to estimate exposures was discussed previously. In most cases, moderate-sized data sets were used as the basis for the source concentrations.

4.6.2.2 Analytical Result Limitations

One aspect of the analytical data that could reduce the level of confidence in the estimates of contaminant concentrations in environmental media is the inclusion of estimated results that may not have the same precision and accuracy as data meeting all of the standard QA criteria. This is a very minor concern.

Another aspect is the use of analytical detection limits that could allow potentially hazardous concentrations of some chemicals to go undetected. Theoretically, the estimated cancer risks that would result if arsenic, beryllium, PCBs, and all of the VOCs were present in drinking water at close to their detection limits could exceed EPA's benchmark risk level of 10⁻⁶. This source of uncertainty reduces the level of confidence that can be placed in the upper limit of the risk associated with environmental media in which these contaminants could be present at or close to their detection limits.

4.6.2.3 Exposure Estimation Calculations

The primary uncertainty regarding the exposure estimation calculations is associated with the selection of appropriate parameter values. The values used and a brief rationale for their selection are provided in the site-specific risk assessments, which describe the exposure calculations for the various pathways evaluated. Individual parameter values were selected so

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that the overall pathway exposure estimates would approximate reasonable maximum exposures that are conservative but still within the range of possible exposures.

4.6.2.4 Steady State Assumption

All of the exposure calculations used in this risk assessment assume that the concentrations of COPCs in the source media are at steady state and remain constant for the duration of the potential exposure periods, which range from 6 years to 30 years. Actual COPC concentrations could remain the same or decrease over these time periods depending on both site-specific and chemical-specific factors.

The RI sites are currently inactive and the sources of present site contamination are now gone. The steady-state assumption appears to be appropriate for inorganic COPCs in soil and sediment. Since they are relatively immobile and do not degrade, the concentrations of inorganic COPCs in soil and sediment will probably change very little over the 6- to 30-year exposure periods of interest. Though some organic compounds, notably pesticides and PCBs, are also relatively immobile and persistent in the environment, they can migrate slowly from soils and, under favorable conditions, they can degrade as a result of chemical or biological transformations suggesting that some COPC concentrations might actually decrease. Volatile and semivolatile organic chemicals can evaporate from surface water and surface and near-surface soils thereby reducing their concentrations in these media over time. Contaminant levels in groundwater could increase (as chemicals leach from soils) or decrease (by dilution, dispersion, or degradation) depending on many site-specific factors.

Because information needed to reliably estimate future concentrations of COPCs is not readily available, the steady state assumption was used.

4.6.3 Other Uncertainties

Two additional factors need to be considered when discussing uncertainties associated with the overall risk characterization: the cumulative effect of using conservative assumptions throughout the process, and the likelihood of the exposures postulated and estimated in the exposure assessment actually occurring.

The cumulative effect of using conservative assumptions throughout the risk estimation process could be to substantially overestimate the true risks. The Risk Assessment Guidance for Superfund Manual (USEPA 1989) recommends that individual parameter values be selected so that the overall estimate of exposure represents a "reasonable maximum exposure." In many cases, the statistical distribution of a parameter is unknown and the risk assessor is left to select a value, using best professional judgment, that is sufficiently conservative to avoid underestimating the true risk, yet not so conservative that the resulting risk estimate turns out to be unreasonably high. When in doubt, the risk assessor will usually elect to err in favor of protecting human health and select a value that results in overestimating the true risk. In summary, the nature of the risk estimation process itself ensures that the true risks are much more likely to be overestimated than underestimated.

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The last uncertainty factor to consider is the likelihood of the postulated exposures actually occurring. The exposure pathways identified as complete under current land use conditions are all plausible and exposure is either presently occurring by these pathways or such exposure could reasonably be expected. The postulated frequencies of occurrence may overestimate average occurrence, but could certainly reflect the reasonable maximum occurrence.

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5. ECOLOGICAL RISK ASSESSMENT APPROACH

5.1 INTRODUCTION

Baseline ecological risk assessments were performed for two RI sites at the Annex. and referred to as the P11/P13 and A12/P36/P37 Sites. This section describes the general approach of these ecological risk assessments.

The ecological risk assessments integrate information gathered from the field investigations with toxicological information to determine whether contamination presents potential risks to ecological receptors. Baseline risks are evaluated for current and future conditions at the site assuming no remedial action. Baseline ecological risk assessments for each site were performed in accordance with current regional and national EPA guidance for ecological assessments at hazardous waste sites. This guidance includes:

- Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual - Interim Final (EPA/540/1-89/001) (USEPA 1989a);
- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (EPA/600/3-89/013) (USEPA 1989b);
- Region I Supplemental Risk Assessment Guidance for the Superfund Program, Part 2, Guidance for Ecological Risk Assessments (USEPA 1989c); and
- Framework for Ecological Risk Assessment (EPA/630/R-92/001) (USEPA 1992).

The objective of the ecological risk assessment is to evaluate environmental samples for site-related contaminants and to estimate any potential risks these contaminants pose to the natural environment. To accomplish this, screening-level ecological risk assessments were conducted. As defined in the EPA Region I guidance, a screening-level risk assessment is "a simple ecological risk assessment that uses available or easily obtainable data and is often based on established criteria and worst case assumptions concerning exposure." The results of these screening-level assessments will determine if more detailed ecological risk assessments are warranted, possibly including toxicity testing of field-collected media, additional chemical analysis of media or biological tissues, modeling, or a variety of bioassessment techniques (USEPA 1989c).

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According to current EPA guidance (USEPA 1992), the process of ecological risk assessment involves a preliminary step called problem formulation, which includes identification of the following:

- Ecosystems of concern;
- Potential stressors, pathways, and effects;
- Ecological endpoints; and
- A conceptual model.

Problem formulation is followed by analysis and characterization of risks, which includes:

- Exposure assessment,
- Ecological effects assessment, and
- Risk characterization.

Each of these steps is described below.

5.2 PROBLEM FORMULATION

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA 1992). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site are then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

Problem formulation is based on information collected during the site-specific ecological characterization and hydrogeological studies, and the chemical data provided from the RI sampling effort. This phase of the ecological risk assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints; and the conceptual model.

5.2.1 Ecosystems of Concern

The upland, wetland, and aquatic ecosystems at the two sites were characterized from available information, government agency contacts, literature and map resources, and field investigations conducted June 21 through 23, 1993. The detailed ecology reports for each site are presented in the site-specific RI reports. Tables 5-1 through 5-4 list the plant, mammal, bird, and amphibian and reptile species, respectively. Table 5-5 lists Federal- and State-listed

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Table 5-1

PLANT SPECIES IDENTIFIED ON THE P11/P13 AND A12/P36/P37 SITES SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	P11/P13	A12/P36/P37
Cottonwood	Populus deltoides ·	х	х
Big-Toothed Aspen	Populus grandidentata	х	х
Red Maple	Acer rubrum	х	Х
Eastern White Pine	Pinus strobus	х	х
Red Pine	Pinus resinosa		Х
Scotch Pine	Pinus sylvestris	х	X
Scarlet Oak	Quercus coccinea	х	х
Northern Red Oak	Quercus rubra		х
White Spruce	Picea glauca		Х
Black Locust	Robinia pseudoacacia	X	
Slippery Elm	Ulmus rubra	X	
American Chestnut	Castanea dentata		X
White Ash	Fraxinus americana	x	
Green Ash	Fraxinus pennsylvanica	X	
Gray Birch	Betula populifolia		x
Red Cedar	Juniperus virginiana	x	
Paper birch	Betula papyrifera		x
Black Cherry	Prunus serotina		х
Fire Cherry	Prunus pensylvanica		х
Shagbark Hickory	Carya ovata	х	
Smooth Sumac	Rhus glabra	х	
Speckled Alder	Alnus rugosa		X
Multiflora Rose	Rosa multiflora	х	
Sweetfern	Comptonia peregrina		х
Lowbush Blueberry	Vaccinium angustifolium	х	X
Winterberry	Ilex verticillata	X	

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Table 5-1

PLANT SPECIES IDENTIFIED ON THE P11/P13 AND A12/P36/P37 SITES SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	P11/P13	A12/P36/P37
Sheep Laurel	Kalmia angustifolia		х
Mountain Laurel	Kalmia latifolia	х	х
Rugosa Rose	Rosa ritida	х	х
Privit	Ligustrum vulgare	х	
Blackberry	Rubus allegheniensis	x	
Meadowsweet	Spirea latifolia	x	х
Alternate-leaved Dogwood	Cornus alternifolia	Х	
Flowering Dogwood	Cornus florida	x	
Common greenbrier	Smilax rotundifolia	х	
Northern Arrowwood	Viburnum recognitum	х	
Wild Grape	Vitis sp.	· X	
Virginia Creeper	Parthenocissus quinquefolia	х	
Field Hawkweed	Hieracium pratense	х	Х
Queen Anne's Lace	Daucus carota	х	х
Little Bluestem	Schizachyrium scoparium	X	
Japanese barberry	Berberis thunbergii	х	
Small Yellow Pond Lily	Nuphar microphyllum		х
Common Cinquefoil	Potentilla simplex	х	х
Sphagnum Moss	Sphagnum sp.	х	х
Indian paintbrush	Hieracium aurantiacum	x	
Field sorrel	Rumex acetosella	x	
White clover	Trifolium repens	х	
Unidentified Goldenrod	Solidago sp.	x	х
Unidentified Aster	Aster sp.	X	Х
Cow Vetch	Vicia cracca	Х	
Rabbit-Foot Clover	Trifolium arvense	х	

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Table 5-1

PLANT SPECIES IDENTIFIED ON THE P11/P13 AND A12/P36/P37 SITES SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	P11/P13	A12/P36/P37
Red Clover	Trifolium pratense	x	
Hop Clover	Trifolium agrarium	Х	
Round-Headed Bush Clover	Lespedeza procumbens	х	х
Yellow sweet clover	Melilotus officinalis		х
White sweet clover	Melilotus alba		х
Dwarf snapdragon	Chaenorrhinum minus	х	
Poverty grass	Danthonia spicata	х	
Panic grass	Panicum sp.	х	
Common Milkweed	Ascelpias syriaca	Х	х
Indian Pipe	Monotropa uniflora	х	
Pink Ladyslipper	Cypripedium acaule	х	х
Canada Mayflower	Maianthemum canadense	Х	х
Yellow Wood Sorrel	Oxalis europaea	х	
Ground Cedar	Lycopodium tristachym		х
Tree Clubmoss	Lycopodium obscurum		х
Stiff Clubmoss	Lycopodium annotinum		х
Yarrow	Achillea millefolium	х	х
Slender Blue Flag Iris	Iris primatica	х	
Timothy grass	Phleum pratense	х	
Rice cut grass	Leersia oryzoides	х	
Reed canary grass	Phalaris arundinacea	х	
Skunk Cabbage	Symplocarpus foetidus	х	
Jack-in-the-Pulpit	Arisaema atrorubens	х	х
Hairy Solomon's Seal	Polygonatum pubescens	х	
Broad-leaved Cattail	Typha latifolia		Х
Royal Fern	Osmunda regalis	х	

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Table 5-1

PLANT SPECIES IDENTIFIED ON THE P11/P13 AND A12/P36/P37 SITES SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	P11/P13	A12/P36/P37
Cinnamon Fern	Osmunda cinnamomea		Х
Sensitive Fern	Onoclea sensibilis	X	Х
Poison Ivy	Toxicodendron radicans		X
Wild Sarsaparilla	Aralia nudicaulis		X
Partridge-Berry	Mitchella repens		Х
Starflower	Trientalis borealis		X
Indian Cucumber-Root	Medeola virginiana	X	
Swamp Candles	Lysimachia terrestris	х	
Whorled Loosestrife	Lysimachia quadrifolia		X
Spotted Jewelweed	Impatiens capensis	х	X
Arrow-Leaved Tearthumb	Polygonum sagittatum	х	
Birds Foot Trefoil	Lotus corniculatus		
Orchard grass	Dactylis glomerata		

Source: Ecology and Environment, Inc. 1994.

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Table 5-2

MAMMAL SPECIES LIKELY TO OCCUR AT SUDBURY ANNEX, MASSACHUSETTS

Common Name Scientific Name	
Virginia opossum	Didelphis virginiana
Smokey shrew	Sorex fumeus
Masked shrew	Sorex cinereus
Short-tail shrew	Blarina brevicauda
Hairytail mole	Parascalops breweri
Star-nosed mole	Condylura cristata
Eastern mole	Scalopus aquaticus
Keen's myotis	Myotis keenii
Little brown myotis	Myotis lucifugus
Silverhaired bat	Lasionycteris noctivagens
Eastern pipistrel	Pipistrellus subflavus
Red bat	Lasiurus borealis
Big brown bat	Eptesicus fuscus
Raccoon ^a	Procyon lotor
Fisher	Martes pennanti
Short-tail weasel	Mustela erminea
Long-tail weasel	Mustela frenata
Mink	Mustela vison
Striped skunk	Mephitis mephitis
Red fox	Vulpes vulpes
Bobcat	Lynx rufus
Woodchuck ^a	Marmota monax
Eastern chipmunk ^a	Tamias striatus
Eastern gray squirrel ^a	Sciurus carolinensis
Red squirrel ^a	Tamiasciurus hudsonicus
Southern flying squirrel	Glaucomys volens
Beaver	Castor canadensis

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Table 5-2

MAMMAL SPECIES LIKELY TO OCCUR AT SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	
Deer mouse	Peromyscus leucopus	
White-footed mouse	Peromyscus leucopus	
Meadow vole	Microtus pennsylvanicus	
Pine vole	Pitymys pinetorum	
Muskrat	Ondatra zibethica	
Meadow jumping mouse	Zapus hudsonius	
Norway rat	Rattus norvegicus	
House mouse	Mus musculus	
Eastern cottontail	Sylvilagus floridanus	
White-tailed deer	Odocoileus virginianus	

a Evidence of these species was observed during the June 1993 field surveys (i.e., scats, tracks, dens, or individuals).

Source: DeGraaf and Rudis 1986.

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Table	5-3
Labic	5-5

BIRDS LIKELY TO BREED OR WINTER WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Pied billed grebe	Podilymbus podiceps
American bittern	Botaurus lentiginosus
Sora	Porzana carolina
Great blue heron	Ardea herodias
Green-backed heron	Butorides striatus
Black-crowned night-heron	Nycticorax nycticorax
Canada goose	Branta canadensis
Wood duck	Aix sponsa
American black duck	Anas rubripes
Mallard	Anas platyrhynchos
Osprey	Pandion haliaetus
Bald eagle	Haliaeetus leucocephalus
Northern harrier	Circus cyaneus
Cooper's hawk	Accipiter cooperii
Sharp-shinned hawk	Accipiter striatus
Broad-winged hawk	Buteo platypterus
Red-tailed hawk ^a	Buteo jamaicensis
Red shouldered hawk	Buteo lineatus
Rough-legged hawk	Buteo lagopus
American kestrel ^a	Falco sparverius
Peregrine falcon	Falco peregrinus
Ring-necked pheasant	Phasianus colchicus
Ruffed grouse ^a	Bonasa umbellus
Wild turkey ^a	Meleagris gallopavo
Killdeer	Charadrius vociferus
Spotted sandpiper	Actitus macularis
Upland sandpiper	Bartramia longicauda

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BIRDS LIKELY TO BREED OR WINTER WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name Scientific Name	
American woodcock	Scolopax minor
Ring-billed gull	Larus delawarensis
Herring gull ^a	Larus argentatus
Rock dove ^a	Columba livia
Mourning dove ^a	Zenaida maxcroura
Black-billed cuckoo	Coccyzus erythrophthalmus
Yellow-billed cuckoo	Coccyzus americanus
Eastern screech owl	Otus asio
Great horned owl	Bubo virginianus
Barred owl	Strix varia
Chimney swift ^a	Chaetura pelagica
Ruby-throated hummingbird	Archilochus colubris
Belted kingfisher	Ceryle alcyon
Downy woodpecker	Picoides pubescens
Hairy woodpecker	Picoides villosus
Northern flicker ^a	Colaptes auratus
Pileated woodpecker	Dryocopus pileatus
Eastern wood-pewee	Contopus virens
Alder flycatcher	Empidonax alnorum
Willow flycatcher	Empidonax traillii
Least flycatcher	Empidonax minimus
Eastern phoebe ^a	Sayornis phoebe
Great crested flycatcher ^a	Myiarchus crinitus
Eastern kingbird ^a	Tyrannus tyrannus
Horned lark	Eremophial alpestris
Purple martin	Progne subis
Tree swallow	Tachycineta bicolor

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Table 5-3

BIRDS LIKELY TO BREED OR WINTER WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Barn swallow	Hirundo rustica
Blue jay ^a	Cyanocitta cristata
American crow ^a	Corvus brachyrhynchos
Black-capped chickadee ^a	Parus atripcapillus
Tufted titmouse	Parus bicolor
Red-breasted nuthatch	Sitta canadensis
White-breasted nuthatch	Sitta carolinensis
Brown creeper	Certhia americana
House wren	Troglodytes aedon
Golden-crowned kinglet	Regulus satrapa
Blue-gray gnatcatcher	Polioptila caerulea
Eastern bluebird	Sialia sialis
Veery	Catharus fuscenscens
Wood thrush	Hylocichla mustelina
American robin ^a	Turdus migratorius
Gray catbird ^a	Dumetella carolinensis
Northern mockingbird ^a	Mimus polyglottos
Brown thrasher	Toxostoma rufum
Cedar waxwing ^a	Bobycilla cedrorum
European starling ^a	Sturnus vulgaris
Yellow-throated vireo	Vireo flavifrons
Warbling vireo	Vireo gilvus
Red-eyed vireo	Vireo olivaceus
Nashville warbler	Vermivora ruficapilla
Yellow warbler	Dendroica petechia
Chestnut-sided warbler	Dendroica pensylvanica
Black-throated blue warbler	Dendroica caerulescens

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Table 5-3

BIRDS LIKELY TO BREED OR WINTER WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Yellow-rumped warbler	Dendroica coronata
Black-throated green warbler	Dendroica virens
Pine warbler	Dendroica pinus
Prairie warbler	Dendroica discolor
Blackpoll warbler	Dendroica striata
Black and white warbler ^a	Mniotilta varia
American redstart	Steophaga ruticilla
Ovenbird ^a	Seiurus aurocapillus
Northern waterthrush	Seiurus noveboracensis
Common yellowthroat ^a	Geothlypis trichas
Canada warbler	Wilsonia canadensis
Scarlet tanager	Piranga olivacea
Northern cardinal ^a	Cardinalis cardinalis
Rose-breasted grosbeak	Pheucticus ludovicianus
Indigo bunting	Passerina cyanea
Rufous-sided towhee ^a	Pipilo erythrophthalmus
American tree sparrow	Spizella arborea
Chipping sparrow	Spizella passerina
Field sparrow ^a	Spizella pusilla
Savannah sparrow	Passerculus sandwichensis
Grasshopper sparrow	Ammodramus savannarum
Song sparrow ^a	Melospiza melodia
Swamp sparrow	Melospiza georgiana
White-throated sparrow	Zonotrichia albicollis
Dark-eyed junco	Junco hyemalis
Snow bunting	Plectrophenax nivalis
Bobolink	Dolichonyx oryzivorus

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Table 5-3

BIRDS LIKELY TO BREED OR WINTER WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	
Red-winged blackbird ^a	Agelaius phoeniceus	
Eastern meadowlark	Sturnella magna	
Common grackle	Quiscalus quiscula	
Brown-headed cowbird ^a	Molothrus ater	
Northern oriole ^a	Icterus galbula	
Purple finch ^a	Carpodacus purpureus	
House finch ^a	Carpodacus mexicanus	
Pine siskin	Carduelis pinus	
American goldfinch ^a	Carduelis tristis	
Evening grosbeak	Coccothraustes vespertinus	
House sparrow ^a	Passer domesticus	

^a Species observed during field surveys conducted June 1993.

Source: DeGraaf and Rudis 1986.

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Table 5-4

AMPHIBIANS AND REPTILES LIKELY TO OCCUR
WITHIN SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name
Spotted salamander	Ambystoma maculatum
Red-spotted newt	Notophthalmus viridescens
Northern dusky salamander	Desmognathus fuscus
Redback salamander	Plethodon cinereus
Northern two-lined salamander	Eurycea bislineata
American toad	Bufo americanus
Spring peeper	Hyla crucifer
Gray treefrog	Hyla versicolor
Bullfrog ^a	Rana catesbiana
Green frog ^a	Rana clamitans
Wood frog	Rana sylvatica
Northern leopard frog	Rana pipiens
Pickerel frog	Rana palustris
Common snapping turtle	Chelydra serpentina
Common Musk Turtle	Sternotherus odoratus
Eastern painted turtle ^a	Chrysemys picta
Northern water snake	Nerodia sipedon
Northern brown snake	Storeria dekayi
Northern redbelly snake	Storeria occipitomaculata
Eastern garter snake	Thamnophis sirtalis
Eastern ribbon snake	Thamnophis sauritus
Northern ringneck snake	Diadophis punctatus
Northern black racer	Coluber constrictor
Eastern smooth green snake	Opheodrys vernalis
Eastern milk snake	Lampropeltis triangulum

a Observed during the June 1993 field surveys.

Source: DeGraaf and Rudis 1986.

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Table 5-5

FEDERAL AND STATE LISTED SPECIES OCCURRING OR SUSPECTED OF OCCURRING AT SUDBURY ANNEX, MASSACHUSETTS

Common Name	Scientific Name	Federal/State Status ^a	Habitat ^c
Birds			
Bald eagle	Haliaeetus leucocephalus	E/E	P
Great blue heron	Ardea herodias	-/WL	P/W
Osprey	Pandion haliaetus	· -/WL	P/W
Red-shouldered hawk	Buteo lineatus	-/WL	0
Purple martin	Progne subis	-/WL	0
Eastern bluebird	Sialia sialis	-/WL	0
Reptiles/Amphibians	_		
Blanding's turtle	Emydoidea blandingi	-/T	P
Spotted turtle	Clemmys guttata	-/SC	P
Blue spotted salamander	Ambystoma laterale	-/SC	w
Spotted Salamander	Ambystoma maculata	-/WL	w
Plants			
Blazing star	Liatris borealis	E (pending)/ WL	0
Grass-leaved ladies'-tresses	Spiranthes vernalis	-/SC	w
Small beggar-ticks	Bidens discoidea	-/WL	w
Lacegrass	Eragrostis capillaris	-/WL	0
Wood witchgrass	Panicum philadelphium	-/SC	0
Few-seeded sedge	Carex oligosperma	-SC	w
Midland sedge	Carex mesochorea	-/E	F
Red pine	Pinus resinosa	-/WL	F
Northern starwort	Stellaria borealis	-/WL	F
Small whorled pogonia	Isotria medeoloides	E/E	W

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Table 5-5 (Cont.)

a

E = Endangered- any species that is in danger of extinction throughout all or a significant portion of its range.

T = Threatened- a species likely to become an endangered species within the foreseeable future throughout all of, or a significant portion of, its range, and any species declining or rare.

SC = Special concern- a species suffering a decline that could threaten it if allowed to continue unchecked, or a species that occurs in such small numbers or with such a restricted distribution or specialized habitat requirements that it could easily become threatened.

WL = Watch list.

- = Indicates not listed.

considered = Indicates that the species is currently under consideration for the status listed.

b Variable = Indicates that the species may occur throughout the base in the appropriate habitat either as a migrant, or occasional or permanent resident.

Unavailable = Indicates that agency maps show appropriate habitat for the species on the Base, but information regarding its presence has not been recorded.

Unconfirmed = Indicates that occurrence of the species on the base has not been recorded, although suitable habitat exists.

C F = Forest.

O = Open, grassy, or shrubby area.

P = Pond, lake, open water.

W = Wetland (i.e., marsh, bog, riverbank, etc.).

Source: Compiled by E & E 1994; Aneptek 1991, Butler 1992, Hunt 1992.

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species of concern. In addition, brief descriptions of the ecosystems of concern for each site are provided in the problem formulation section of each ecological risk assessment.

5.2.2 Potential Stressors, Pathways, and Effects

A variety of potential ecological stressors exists at the sites. In each of the ecological risk assessments, chemical stressors and affected media are screened to identify COPCs. The identification of COPCs for ecological receptors was based on the following considerations (USEPA 1989a). Only chemicals found to be useable for assessing site-related contamination were evaluated, as described in Section 6 of each site-specific report. For each of the affected media, levels of chemicals detected at the site were compared to local and regional background concentrations (see Section 6 of the site-specific reports). Chemicals exceeding background also were compared with ecological risk-based criteria derived or obtained from published sources. Chemicals not detected above these background or risk-based criteria were removed from consideration as COPCs. The phytotoxicity values used in screening soil contaminants are generally conservative and likely to be protective of wildlife. This is illustrated by Table 5-6a, which compares the lower phytotoxicity values with the wildlife NOAELs for five selected contaminants. For most of the listed contaminants, the lower phytotoxicity value is less than the wildlife NOAEL. In addition, a low frequency of occurrence in environmental media, limited areal extent of contamination, and the absence of plausible exposure pathways also were considered to be reasons for eliminating chemicals from consideration as COPCs.

The selected screening criteria used in the comparisons are summarized in Table 5-6b. The results of the screening for chemicals exceeding background concentrations and ecological risk-based criteria are presented in the individual ecological risk assessments. Chemicals of potential ecological concern for the P11/P13 and A12/P36/P37 sites are summarized in Table 5-7.

The general classes of potentially exposed ecological receptors, pathways, and exposure media for the P11/P13 and A12/P36/P37 sites are summarized in Table 5-8. Only the pathways considered to have potentially significant adverse effects on ecological receptors are shown in this table. Terrestrial plants and soil invertebrates inhabiting the actual sites could be affected by soil contamination, and terrestrial wildlife could have incidental contact with site soils (see Table 5-8). At these two sites, an array of aquatic and terrestrial receptor types could be exposed to COPCs because of the presence of contaminants in sediment and surface water in the wetland areas adjacent to the site. Aquatic and semi-aquatic wildlife inhabiting the wetland areas could be exposed to site contaminants (see Table 5-8).

5.2.3 Ecological Endpoints

Ecological endpoints are receptor characteristics that may be adversely affected by site contaminants. Ecological risk assessment guidance specifies two types of endpoints, assessment and measurement (USEPA 1992). Assessment endpoints are expressions of environmental values to be protected from site contaminants. Measurement endpoints are measurable responses to contaminants that can be related to the assessment endpoints.

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	Table 5-6a			
COMPARISON OF BACKGROUND,	PHYTOTOXICITY,	AND	WILDLIFE	NOAELS

Contaminant	Sudbury Background (mg/kg)	Lower Phytotoxicity Value (mg/kg)	Wildlife NOAEL Bird (ppm) ^a	Wildlife NOAEL Mammal (ppm) ^a
Antimony	0.5	5	NA	5 ^a
Beryllium	0.446	10	NA	5 ^a
Cadmium	0.5	3	15.2	10.1
Mercury	0.318	0.3	0.5	1.1
Selenium	0.571	1.6	5	5

^a Expressed as ppm due to superscripted NOAELs being based on doses in water.

Source: E & E 1994, Opresko et al. 1994, Kabata-Pendias and Pendias 1992.

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Table 5-6b

SCREENING CRITERIA FOR CHEMICALS OF POTENTIAL **ECOLOGICAL CONCERN**

		Ecological Risk-Based Criteria		
Media	Background	Criteria	Basis	Source
Soils	Local surface soils	Phytotoxicity	Values are the range of concentrations regarded as phytotoxic by various authors.	Kabata-Pendias and Pendias 1992
Sediments	Local sediments; regional sediments (see Appendix J)	Ontario Ministry of the Environment provincial sediment quality guidelines	Criteria derived from the equilibrium partitioning approach and the screening level concentration approach for in situ benthic communities.	Persaud 1993
		Wisconsin Department of Natural Resources sediment quality guidelines	Criteria derived from sediment background concentrations from areas of Wisconsin not subject to influence of contamination.	Bennett and Cubbage 1991
		National Oceanic and Atmospheric Administration sediment guidelines	Criteria are the Effects Range Low (ERL), defined as the lower 10 percentile of concentrations observed or predicted to be associated with biological effects.	Long and Morgan 1991
Surface water	Local surface water	EPA Ambient Water Quality Criteria	Criteria are the freshwater acute and chronic values for the protection of aquatic life.	USEPA 1986d; USEPA 1993b
Groundwater	Upgradient wells			

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Table 5-7 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN P11/P13 AND A12/P36/P37 SITES

Chemical	Surface Water	Sediment	Surface Soil
Arsenic	_	Х	_
Cadmium	-	_	Х
Copper		_	Х
Lead	x	_	x
Zinc	x	_	х
Aroclor 1260	_	_	X

Key:

X = Selected as a COPC for the ecological risk assessment.

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Table 5-8			
POTENTIALLY SI	IGNIFICANT ECOLOGICAL EX	XPOSURE PATHWAYS	
Receptor Type	Exposure Pathways	Exposure Medium	
Terrestrial plants	Uptake by roots	Soil	
Invertebrates	Contact with and ingestion of contaminated media and food items	Soil	
Terrestrial wildlife	Incidental contact with and ingestion of contaminated media and food items	Soil and surface water	
Wetland plants	Uptake by roots	Sediment	
Aquatic invertebrates	Contact with and ingestion of contaminated media and food items	Sediment and surface water	
Aquatic/semi-aquatic wildlife	Contact with and ingestion of contaminated media and food items	Sediment, surface water, and soil	

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Criteria used for the selection of assessment endpoints for site investigations include the following: regulatory and social significance; ecological relevance; amenability to measurement or prediction; and susceptibility to contaminants (USEPA 1992). Social significance indicates that the endpoint species has value to the public or to regulatory agencies (e.g., game animals or endangered species). Ecological relevance refers to the role of the endpoint species in the ecosystem or community. Measurability indicates that some measurement exists for the endpoint, be it an actual measurement of the response of ecological receptors to COPCs at the site, or a toxicity reference value derived from the literature. Susceptibility to contaminants indicates the potential for the endpoint species to be exposed and adversely affected by the site contaminants.

In accordance with the selection criteria mentioned above, ecological endpoint species were chosen based on their abundance and reproductive activities in the general vicinity of the various sites. Information regarding population sizes, density, breeding activities, and habitat selection was obtained from published and unpublished sources provided by the installation naturalist/biologist, the U.S. Fish and Wildlife Service, and the Biology Department of Fitchburg State University. In general, only those species that commonly occur on site and are known to breed in the area were selected as endpoint species. However, other than the endangered plant surveys conducted by Aneptek (1991) and Hunt (1992), no detailed population studies have been conducted for endpoint species at the Annex. A more detailed discussion of the selection of ecological endpoints at each site is provided in the ecological risk assessments.

Assessment endpoints are the estimated effects of site contaminants on growth, reproduction, or survival of representative species, since it is impossible to evaluate the effects of contamination on all potentially exposed receptors. Potential assessment endpoints may be evaluated at the individual, population, community, or ecosystem level.

Evaluation of the effects of site contaminants on ecological receptors at the P11/P13 and A12/P36/P37 sites were limited to the set of representative indicator species shown in Table 5-9. Endpoints evaluated for these species vary with species type, contaminant type, and availability of toxicological information.

5.3 EXPOSURE ASSESSMENT

The general approach to exposure assessment for the P11/P13 and A12/P36/P37 sites involves deriving exposure estimates for the endpoint species identified in the problem formulation step. To derive these estimates, assumptions were made regarding the ecological receptors' co-occurrence and contact with, and uptake of, COPCs. Since default exposure parameters were not available for the ecological risk assessment, these parameters were derived from published or readily available information, as described in this section. In addition, the behavior of contaminants in the environment is summarized in this section to provide general background information for the exposure assessment.

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Table 5-9

ENDPOINT SPECIES FOR THE P11/P13 AND A12/P36/P37 **ECOLOGICAL RISK ASSESSMENTS**

Receptor Type	Endpoint Species
Terrestrial plants	Various species of grasses and herbaceous plants
Small mammals	White-footed mouse
Upland birds	American robin
Terrestrial carnivores	Red fox
Aquatic invertebrates	Various species of benthic and/or water column invertebrates
Wetland herbivore	Meadow vole
Semi-aquatic predators	Raccoon

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5.3.1 Contaminant Release, Migration, and Fate

This section describes the environmental processes affecting the fate and transport of contaminants of ecological concern identified at the Sudbury Training Annex.

5.3.1.1 Fate and Transport of Metals

Several metals, including arsenic, cadmium, copper, lead, and zinc were found at elevated levels in environmental media at the P11/P13 and A12/P36/P37 sites. Volatilization, photolysis, hydrolysis, and biodegradation are not important fate processes for metals.

In areas that are not directly impacted by site activities, atmospheric deposition is most likely the primary source of metals. Since the advent of industrialization, emissions of trace metals to the atmosphere have increased markedly (Nriagu and Pacyna 1988) so that atmospheric deposition is now the principal source of trace metals to most terrestrial and aquatic systems. Recent reviews (e.g., Campbell et al. 1985) have shown that in eastern North America, the rates of atmospheric deposition of arsenic, cadmium, copper, mercury, manganese, nickel, lead, selenium, silver, vanadium, and zinc are controlled by anthropogenic activities. There are other metals (beryllium, cobalt, and thallium) whose rates of deposition probably have increased, but data are lacking (Campbell et al. 1985).

In a terrestrial setting, metals that are released to the environment accumulate in soil (Sposito and Page 1984). Metal retention by soils is dependent primarily on the soil cation exchange capacity (CEC) and soil pH. Sandy soils, such as those found at Fort Devens Sudbury Training Annex, characteristically have low CECs and, thus, have a low potential to retain metals. The low CECs of these soils, along with the characteristically low pH of precipitation in eastern North America (e.g., Munger and Eisenreich 1983), suggest that metals in soils at the Annex could be mobilized to deep soil layers, to groundwater, or to the aquatic environment. Several reviews (e.g., LaZerte 1986) have shown that aluminum, manganese, zinc, and possibly cadmium and nickel can be mobilized from soils by acidic precipitation. Conversely, lead and possibly copper are not expected to be mobilized. Other trace metals most likely fall between these extremes, but there are fewer data available from which to draw conclusions (LaZerte 1986).

Metals mobilized from soils to aquatic systems generally accumulate in bottom sediment. Even acidic lakes remain net metal sinks, although they retain less of the metals (aluminum, lead, manganese, zinc, and possibly cadmium and nickel) in their sediments than more neutral lakes (LaZerte 1986).

5.3.1.2 Fate and Transport of PCBs in the Terrestrial Environment

When released into the environment PCBs become tightly bound to soil particles, except in the presence of nonpolar organic solvents. Therefore, the migration of PCBs through surface soils is slow. Over time, PCB loss occurs through biodegradation, volatilization, and migration downward as water solute. The rate of loss depends on the geohydological conditions at the site; PCBs are more tightly bound in soils with high clay or

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organic matter content. PCBs in the surface soils can also be transported on particles during runoff and carried to lakes and rivers (Sklarew and Girvin 1987).

Uptake of PCBs by plants is higher in sandy soils than in clay or organic soils. Bioaccumulation of PCBs by plants is low for plants growing in aerobic soils, but is higher for plants growing in flooded soils (Sklarew and Girvin 1987). Thus, plants are not likely to be an avenue of transport for PCBs from the soil to higher trophic levels under dry conditions. Under wet or aquatic conditions, transport to higher trophic levels is more likely.

5.3.2 Exposure Scenarios, Pathways, and Estimates

This section of each of the ecological risk assessments evaluates the exposure of ecological receptors to COPCs at the P11/P13 and A12/P36/P37. The exposure routes and receptors identified in problem formulation were quantitatively evaluated to the extent possible. Similar to the human health risk assessment, two cases were evaluated for each exposure route and receptor. The average exposure case was based on the average contaminant concentration measured or estimated in the exposure media in a given area; the RME case used the highest observed or estimated contaminant concentrations.

Exposure point concentrations (EPCs) are presented for the COPCs in soil, sediment, and surface water; average and maximum EPCs are estimated from the field data. Then, exposure scenarios and pathways were developed for the endpoint species and quantitative estimates of exposure were derived for average and maximum exposure cases.

Dietary exposure for ecological receptors was calculated by multiplying each prey species' tissue concentration by the proportion of that prey in the diet, summing these values, multiplying by the receptor's site use factor (SUF), exposure duration (ED), and ingestion rate (IR), and dividing by the receptor's body weight (BW). Dietary exposure is represented mathematically as:

$$EE_{diet} = \frac{\sum_{1-n} \left[\left(P_1 \times T_1 \right) + \left(P_2 \times T_2 \right) + ... \left(P_n \times T_n \right) \right] \times SUF \times ED \times IR}{BW}$$

EE_{diet} = Estimated Exposure from diet (mg/kg BW · day); where:

P_n = Percentage of diet represented by prey item ingested;

T_n = Tissue concentration in prey item n (mg/kg dry weight), calculated by multiplying the chemical concentration in media (or food item) by a food chain transfer coefficient:

SUF = Site use factor (unitless), equal to the area of contaminated site (acres) divided by area of home range (acres);

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ED = Exposure duration (unitless), equal to the fraction of the year spent in the region;

IR = Ingestion rate of receptor (kg DW/day); and

BW = Body weight of receptor (kg).

Literature sources for dietary, home range, and body weight information for the receptor species are summarized in USEPA (1993c). Food ingestion rates were calculated from the intake formulas presented in Suter (1993) and USEPA (1993c); or from empirical food ingestion rates provided in USEPA (1993c); the equations are listed in Table 5-10. To estimate drinking water intake, measured water ingestion rates were taken from USEPA (1993c), or the following formula from Suter (1993) was used:

water intake
$$(L/day) = 0.093BW^{0.7584}$$

where:

BW = body weight in kg.

An exposure duration value of 1.0 was used for receptor species that are year-round residents of Massachusetts; a value between 0 and 1.0 was used for migratory species based on the fraction of the year spent in the state. The site use factor was calculated by dividing the site area by the home-range area (to a maximum of 1.0).

Receptor exposure to chemicals from soil (or sediment) ingestion was estimated by multiplying the soil concentration by the percentage of soil in the diet of each receptor, multiplying by the SUF, ED, and IR, and dividing by BW. Soil ingestion data for wildlife were taken from USEPA (1993c). An analogous approach was taken to estimate exposure to chemicals from drinking surface water.

The total exposure of a receptor to a chemical was calculated as the sum of the diet, soil (or sediment), and drinking water dosages:

$$EE_{total} = EE_{diet} + EE_{soil/sediment} + EE_{water}$$

where:

 EE_{total} = Total exposure (mg/kg BW · day);

 EE_{diet} = Estimated exposure from diet (mg/kg BW · day);

EE_{soil/sediment} = Estimated exposure from soil (or sediment) ingestion (mg/kg BW · day);

EE_{water} = Estimated exposure from water ingestion (mg/kg BW · day).

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Table 5-10		
FOOD INTAKE FORMULAS FOR WILDLIFE		
Food Intake Formula ^a Wildlife Group (g/day)		
Eutherian Mammals	$IR = 0.235(bw)^{0.822}$	
Rodents	$IR = 0.621(bw)^{0.564}$	
Herbivores	$IR = 0.577(bw)^{0.727}$	
Birds	$IR = 0.648(bw)^{0.651}$	
Passerine Birds	$IR = 0.398(bw)^{0.850}$	
Reptiles	$IR = 0.013(bw)^{0.773}$	

a Dry-weight basis.

Key:

IR = Ingestion Rate.

bw = Body weight (g), fresh weight.

Source: Nagy 1987 as presented in USEPA 1993c.

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Plant uptake factors for metals from soil were taken from Baes *et al.* (1984). Plant uptake factors for organic contaminants from soil were calculated from the octanol-water partition coefficient using the approach described by Travis and Arms (1988).

When data were available, E & E calculated site-specific food chain transfer coefficients for COPCs for animal species. For example, the bioaccumulation factor (BAF) for arsenic in fish was calculated by dividing the arsenic concentration in whole yellow perch from Puffer Pond by the arsenic concentration in sediment from the pond (E & E 1994). Calculating the BAF in this manner incorporates all the processes that result in the transfer of arsenic from sediment to fish.

When site-specific data were not available, BAFs for chemicals were taken from the literature or calculated from literature data. Data on chemical concentrations in wild animals, as opposed to domestic or laboratory animals, were used when available. For example, the food-chain transfer coefficient for lead in small mammals was calculated from data in Beyer et al. (1985) by dividing the average lead concentration in white-footed mice from a site in eastern Pennsylvania by the average lead concentration in plants and invertebrates from the site; plants and invertebrates are the principal food of the white-footed mouse (Martin et al. 1951).

When BAFs for animal species could not be calculated from site-specific data or estimated from the literature, conservative assumptions were used.

Plant uptake factors for COPCs at the P11/P13 and A12/P36/P37 sites are listed in Table 5-11. Food chain transfer coefficients and bioaccumulation factors for invertebrates, small mammals, birds, fish, and herptiles are provided in Tables 5-12 through 5-18.

5.4 ECOLOGICAL EFFECTS ASSESSMENT

The purpose of the ecological effects assessment is to describe the toxic effects associated with the identified COPCs in each medium of concern. The toxicological evaluation involves characterizing the inherent toxicity of the COPCs and establishing toxicity reference values (TRVs) for each identified COPC.

The known effects of the COPCs for the P11/P13 and A12/P36/P37 sites are described in Section 5.4.1. Section 5.4.2 describes the methodology for the derivation of the TRVs. Section 5.4.3 summarizes the field investigations conducted to evaluate ecological effects of COPCs at the sites.

5.4.1 Ecological Effects Summaries

A toxicity profile summarizing the potential adverse ecological effects of each COPC was derived from the literature. The profiles include effects of COPCs on growth, reproduction, and survival of endpoint species or their surrogates. These summaries, in addition to established criteria, were used to identify the critical effects of COPCs.

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			Table 5-11	
		UPTAKE	UPTAKE FACTORS FOR PLANTS	
Exposure Medium	Chemical	Uptake Factor ^a	Remark	Reference
Soil or	Arsenic	0.040	Vegetative parts (i.e., leaves and shoots).	Baes et al. 1984
Sediment	Cadmium	0.55		
	Copper	0.40		
	Lead	0.045		
	Zinc	1.5		
	Aroclor 1260	0.0015	Estimated from Kow	Travis and Arms 1988
Surface water	Lead	84	Calculated from the Pb concentration in bur-reed (Sparganium spp) and water.	Albers and Camardese 1993
	Zinc	280	Calculated from the Zn concentration in bur-reed (Sparganium) and water	

^a Dry weight (DW) basis. For soil or sediment, all factors are (plant DW concentration/soil or sediment DW concentration). For surface water, all factors are relative to water (plant DW concentration/water concentration).

Source: Ecology and Environment, Inc., 1994.

ecology and environment

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Beyer and Cromartie 1987

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FOOD-CHAIN TRANSFER COEFFICIENTS FOR TERRESTRIAL INVERTEBRATES						
Chemical	Transfer Coefficients ^a	Remark	Reference			
Lead	0.18	Calculated by dividing the metal concentration in foliage-eating insects by the metal concentration in foliage from the same site.	Beyer et al. 1985			
Zinc	1.4					
Copper	1.20					
Cadmium	0.57					
Aroclor 1260	1	Conservative assumption.	None			

Calculated by dividing the arsenic concentration in earthworms by the arsenic concentration in

soil from the same site.

0.31

Source: Ecology and Environment, Inc., 1994.

Arsenic

^a From food to invertebrate: (invertebrate DW concentration)/(food DW concentration).

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Table 5-13 CALCULATION OF BAFS FOR TERRESTRIAL **INVERTEBRATES**

Chemical	Plant Uptake Factor ^a	Transfer Coefficient ^b	BAFc
Lead	0.045	0.18	0.0081
Zinc	1.5	1.4	2.1
Arsenic	0.040	0.31	0.012
Cadmium	0.55	0.57	0.31
Copper	0.40	1.20	0.48
Aroclor 1260	0.0015	1	0.0015

a See Table 5-11.

b See Table 5-12.

^C Dry weight basis, relative to the chemical concentration in soil. Plant uptake factor multiplied by invertebrate transfer coefficient, assuming plants are 100% of the invertebrate diet. For example, for lead: $BAF = 0.045 \times 0.18 = 0.0081$.

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Table 5-14 FOOD-CHAIN TRANSFER COEFFICIENTS FOR SMALL MAMMALS							
Chemical	Transfer Coefficients ^a	Remark	Reference				
Lead	0.48	Calculated by dividing the metal concentration in white-footed mouse carcass by the metal	Beyer et al. 1985 for metals data; Martin et al. 1951				
Zinc	1.3	concentration in plants and invertebrates from the same site. The mouse diet was assumed to be 54% plant materials and 46% invertebrates.	for diet.				
Cadmium	0.88						
Copper	0.26						
Arsenic	2.97	Calculated from data for laboratory rats by dividing the arsenic concentration in muscle by arsenic concentration in feed. The resulting value of 0.86 was converted to a DW bases by assuming a moisture content of 71.4% for mammal muscle tissue.	Woolson 1975 for arsenic data Talmage et al. 1991 for tissue moisture.				
Aroclor 1260	4.1	Determined from cattle vegetative intake	Fries and Paustenbach 1990				

a From food to mammal; (mammal DW concentration)/(food DW concentration).

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		Table	5-15		
CALCULATION	OF I	BAFs	FOR	SMALL	MAMMALS

Chemical	Plant Uptake Factor ^a	Terrestrial Invertebrate BAF ^b	Transfer Coefficient ^c	Small Mammal BAF ^d
Antimony	0.20	0.20	1	0.20
Arsenic	0.04	0.012	2.97	0.081
Cadmium	0.55	0.31	0.88	0.39
Copper	0.40	0.48	0.26	0.10
Lead	0.045	0.0081	0.48	0.0135
Zinc	1.5	2.1	1.3	2.31
Aroclor 1260	0.0015	0.0015	4.1	0.0061

a See Table 5-11.

b Relative to soil; see Table 5-13.

^C From food to mouse; see Table 5-14.

d Relative to chemical concentration in soil. Weighted average of plant uptake factor and invertebrate BAF multiplied by small mammal transfer coefficient. The small mammal diet was assumed to be 54% plants and 46% invertebrates. For example, for lead: BAF = $[(0.045 \times 0.54) + (0.0081 \times 0.46)] \times 0.48 = 0.0135$.

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Table 5-16							
FOOD-CHAIN TRANSFER COEFFICIENTS FOR BIRDS							
Chemical	Transfer Coefficients ^a	Remark	Reference				
Arsenic	1.37	Calculated from data for chickens by dividing the arsenic concentration in liver by the arsenic concentration in diet. The resulting value of 0.40 was converted to a dry weight basis by assuming a moisture content of 71% for chickens.	Woolson 1975 for arsenic data; Suter 1993 for tissue moisture				
Lead	0.62	Calculated by dividing the average metal concentration in songbird carcass by the metal concentration in plant materials and invertebrates from the same site. The bird diet was assumed to be 90% invertebrates and 10% berries.	Beyer et al. 1985 for metals data.				
Zinc	0.44	×I					
Cadmium	0.98						
Copper	0.20						
Aroclor 1260	4.1	Determined from cattle vegetative intake.	Fries and Paustenbach 1990				

a From food to bird; (bird DW concentration)/(food DW concentration).

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Table 5-17 CALCULATION OF BAFs FOR BIRDS								
Plant Invertebrate Transfer Bird Chemical Uptake Factor BAF Coefficient BAF								
Arsenic	0.04	0.04	1.37	0.055				
Cadmium	0.55	0.31	0.98	0.017				
Copper	0.40	0.48	0.20	0.0038				
Lead	0.045	0.0081	0.62	0.0073				
Zinc	1.5	2.1	0.44	0.90				
Aroclor 1260	0.0015	0.0015	4.1	0.0061				

a See Table 5-11.

b Relative to soil; see Table 5-13.

^C From food to bird; see Table 5-16.

d Relative to chemical concentration in soil. Weighted average of plant uptake factor and invertebrate BAF multiplied by bird transfer coefficient. The bird diet was assumed to be 10% plants and 90% invertebrates. For example, for lead: BAF = $[(0.045 \times 0.10) + (0.0081 \times 0.90)] \times 0.62 = 0.0073$.

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Table 5-18							
BAFs FOR FISH, HERPTILES, AND BENTHIC INVERTEBRATES ^a							
Chemical	BAFb	Remark	Reference				
Lead	122	Fish/water BAF. Calculated by dividing the metal concentration in pumpkinseed sunfish from an unpolluted river in Maine by the metal concentration in river water.	Friant 1979				
Zinc	1,633						
Arsenic	0.008	Fish/sediment BAF. Calculated by dividing the average arsenic concentration in whole yellow perch from Puffer Pond by the average arsenic concentration in sediment from the pond.	E & E 1994				

a Herptiles and benthic invertebrates were assumed to accumulate chemicals from the aquatic environment to the same degree as fish.

b Dry weight (DW) basis. A moisture content of 63% was assumed for fish tissue when converting contaminant concentrations in fresh fish tissue to a dry weight basis (Suter 1993).

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Following is a discussion of the acute and chronic toxicity to plants and animals from COPCs at the P11/P13 and A12/P36/P37 sites. The tendency of COPCs to bioconcentrate or bioaccumulate is also discussed.

Arsenic

Arsenic is a naturally-occurring element which is usually present in the environment combined with oxygen, chlorine, sulphur, carbon, and hydrogen. The principle form is arsenic trioxide (Eisler 1988a). Organic arsenic forms typically are less toxic than inorganic forms (ATSDR 1993).

Single-dose oral LD₅₀ (lethal dose to 50 percent of population) values of arsenic in rats range from 15 mg/kg (Harrison et al. 1958) to 110 mg/kg (Gaines 1960). The NOAEL value for the rat cardiovascular system is 2.3 mg/kg/day, and the LOAEL is 11 which resulted in decreased vasoreactivity (Bekemeier and Hirschelmann 1989). NOAEL values of 12 and 1.2 were reported for respiratory, carciovascular, gastrointestinal, and hematopoietic systems in rats and dogs, respectively (Byron et al. 1967).

Oral LD₅₀ values for birds include 99.8 mg of copper acetoarsenite and 47.6 mg of sodium arsenite per kilogram of body weight for brown-headed cowbirds (Hudson et al. 1984) and California quail, respectively (NAS 1977). The NOAEL value for nestling northern bobwhites, mockingbirds, and robins is 40 mg of arsenic (NAS 1977).

Concentrations of arsenic in plants grown in uncontaminated soils vary from 0.009 to 1.5 ppm dry weight with leafy vegetables in the upper range and fruits in the lower range. However, toxicity has been shown in plants grown in contaminated soil. The symptoms of arsenic toxicity include leaf wilting, violet coloration (increased anthocycanin), root discoloration, cell plasmolysis, and growth reduction (Kabata-Pendias and Pendias 1992).

Cadmium

Cadmium, a relatively rare heavy metal, is not biologically essential or beneficial; on the contrary, as reported by Eisler (1985), cadmium is a known teratogen and carcinogen for fish and wildlife.

Cadmium accumulates readily in soil organisms. Earthworms can contain 11 times more cadmium than is present in their surrounding soil (Sharma 1980).

Mammals and birds are comparatively resistant to the toxic properties of cadmium. The lowest oral doses producing death in rats and guinea pigs ranged from 150 to 250 mg/kg body weight. Chickens and mallards had suppressed egg laying when fed a diet containing 200 ppm for 90 days (Eisler 1985).

Cadmium may bioaccumulate through the food chain or media, but does not significantly biomagnify in food chains. For example, in a review of field and experimental

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studies of food chain transfer of metals from sediments, cadmium concentrations generally decreased in higher trophic levels or showed no consistent pattern (Campbell et al. 1985).

Plants grown on contaminated soils do not accumulate high amounts of cadmium until level in soil is very high (Sharma 1980). Cadmium is concentrated in the roots and to a lesser extent the leaves (Kabata-Pendias and Pendias 1992). Terrestrial plants have been shown to exhibit moderate growth reduction when cultivated in soils heavily contaminated with cadmium (Environment Canada (EC) 1983).

Copper

Copper is an essential trace element that is widely distributed in animal and plant tissue. Plant uptake can be a source of copper in the food chain.

Soils with considerable levels of copper exhibit decreased growth of vegetation. Some plants species, such as lichens and mosses, are very sensitive to copper, and community composition and species diversity changes could occur as a result of the elimination of sensitive species and selection for resistent ones. Grasses generally can accumulate copper at high levels, while tree foliage accumulate lower amounts. Copper is highly toxic to roots, but it is not readily translocated and is found in only trace amounts in stems (Gough *et al.* 1979). The major symptom of copper toxicity in plants is chlorosis (yellowing) of the foliage.

Both Gooneratne et al. (1980) and Underwood (1977) have shown ruminants, especially sheep, to be sensitive to copper poisoning. Ingestion of 1.5 g/day for 30 days was fatal to sheep. Copper concentrates in the liver and kidneys, and the resulting primary effect of copper seems to be hepatic changes. Similar studies have not been conducted with wildlife.

Beck (1961) observed that ducks stored copper in liver tissue more rapidly than other birds. Canada geese suffered acute toxicosis following ingestion of 600 mg/kg. Pathological and toxicological changes included necrosis and sloughing of the mucosal of the gizzard, small hemorrhages in the liver, and greenish discoloration of lung tissue (Henderson and Winterfield 1974).

The acute toxicity of copper to aquatic organisms decreases as water hardness and alkalinity increase. Chronic toxicity, however, is not as strongly influenced by hardness and alkalinity. Aquatic species that seem especially sensitive to copper toxicity are daphnids, scuds, midges (chironomids), and snails. These are important food organisms for fish (USEPA 1987b), and their elimination could result in decreased fish production. Sensitive fish species could be eliminated by elevated copper in water and replaced by more resistant, but less desirable, species.

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Lead

The adverse effects of dissolved lead salts on aquatic organisms have been widely reported. Toxicity is generally much greater in soft than in hard water. Hardness decreases the bioavailability of lead, and may also reduce toxicity by influencing the calcium status of organisms (Eisler 1988). Species vary in their sensitivity to lead, with some freshwater benthic macroinvertebrates (e.g., amphipods in the genus *Gammarus*) among the most sensitive, whereas other benthic macroinvertebrates (e.g., chironomid midges in the genus *Tanytarsus*) are among the least sensitive in short-term tests (USEPA 1985). Snails have also been reported to be sensitive to chronic lead exposure (USEPA 1985). The toxic effects of lead on aquatic invertebrates are largely due to inhibition of heme formation and other metabolic effects, as reviewed by Eisler (1988).

Community structure of benthic organisms has been reported to be adversely affected by lead pollution in a variety of freshwater systems. Effects on communities include decreased species richness, and reduced abundances of sensitive species. On the other hand, no toxicity was observed in some sediments contaminated with up to 277 ppm lead (Long and Morgan 1991), perhaps as a result of low lead bioavailability in these sediments.

In general, aquatic plants tend to be less sensitive than macroinvertebrates to dissolved lead (USEPA 1985; WHO 1989b). Lead interferes with chlorophyll formation in plants (Eisler 1988). Uptake of significant amounts of lead by aquatic plants from contaminated sediments is known to occur, although adverse effects have not been widely reported.

Most of the inorganic lead in soils is in a form unavailable to plants, due to the tendency of lead to form insoluble precipitates and complexes. Lead that is taken up by plants is generally stored in the roots and does not affect the health of the plant. Translocation of lead to stems, leaves, and fruits or seeds is limited. Airborne lead may adhere to plant hairs and cuticles, and some of this lead could be absorbed into plant cells.

Absorbed lead inhibits respiration and photosynthesis in plants at very low tissue concentrations. However, lead poisoning in plants is seldom observed under field conditions (Kabata-Pendias and Pendias 1992). In some plant species, lead-resistant populations have been found to tolerate extremely high soil and tissue levels of lead. High levels of lead in soil limits the biological activity of microbes and slows the decomposition of organic matter. This can have an important ecological effect on nutrient cycling if large land areas are affected.

Some soil invertebrates, such as earthworms and woodlice, accumulate lead from soils. However, lead bioaccumulation factors of less than 1 have been reported for earthworms (Beyer *et al.* 1992) and for woodlice (Hopkins *et al.* 1986). Woodlice and earthworms are fairly resistant to toxic effects of lead. Very little data are available on lead toxicity to other species of soil invertebrates.

Lead poisoning in waterfowl is considered an important source of mortality. Numerous cases of mass die-offs of diving ducks, dabbling ducks, geese, and swans have been linked to lead poisoning. Spent shot from hunters is the main source of lead causing

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mortality in waterfowl (Eisler 1988). The effects of lead in the diet have not been documented to affect waterfowl or other birds to nearly the same degree as ingested lead shot. Laboratory studies have shown that high dietary dosages of inorganic lead salts affect food consumption and reproduction in some birds. Adverse effects of exposure to inorganic lead through the food chain have not been widely reported for birds in the field, however.

Lead has a wide range of toxicity levels for of mammals. The acute toxicity levels for oral exposure ranged from 5 to 108 mg/kg in rats. The chronic toxicity oral exposure levels for lead ranged from 0.32 mg/kg in dogs to 1.7 mg/kg in horses (Eisler 1988).

Polychlorinated Biphenyls (PCBs)

PCBs consist of a group of 209 compounds with varying toxicity. A smaller subset, however, are significant for environmental exposure. Two of the latter are known by the trade names Aroclor 1254 and Aroclor 1260. Acute oral LD $_{50}$ s for Aroclor 1254 vary from 1,010 mg/kg in rats to 4,000 mg/kg in mink (Garthoff *et al.* 1981 and ATSDR 1993a). For Aroclor-1260, the rat acute oral LD $_{50}$ was measured at 1,315 mg/kg (ATSDR 1993). Causes of death in acute poisoning included progressive dehydration and central nervous depression; liver and kidney damage was also noted (WHO 1976).

Chronic and subchronic exposure to PCBs can cause a variety of systemic effects, with hepatic and renal systems generally the most sensitive. Hornshaw *et al.* (1986), report a 28-day LD₅₀ for Aroclor 1254 in mink of 7 mg/kg, with cardiac, hepatic, and renal damage seen. The NOAEL in this study was 1.1 mg/kg/day. Reproductive effects were not seen at 0.1 mg/kg/day in mink for Aroclor 1254 (ATSDR 1993a). For Aroclor 1260, the guinea pig NOAEL was 2.0 mg/kg/day over 8 weeks. PCBs are lipophilic and have been shown to bioaccumulate in aquatic systems (WHO 1976).

The acute oral LD_{50} for Aroclor 1254 in mallards was greater than 2 g/kg (WHO 1976). The Aroclor 1254 LOAEL for chickens exposed subchronically was 100 mg/kg (WHO 1976). For Aroclor 1260, no effect was seen at this exposure level. Edema of the abdominal and peritoneal cavities has been noted in bird mortality, as well as enlargement of the liver and kidneys (WHO 1976). Exposure of mallards to 40 ppm of Aroclor 1254 in feed did not have significant impact on reproduction (Risebrough and Anderson 1975).

Zinc

Zinc is a nutrient essential for the growth and development of all living organisms. For this reason, organisms have evolved mechanisms to accumulate zinc from water and food. While many organisms can tolerate greater amounts of zinc than are needed, a sufficiently high excess could yield adverse effects. The range of maximum zinc concentration that is tolerated varies among different species and even individuals.

Zinc occurs in many forms in natural media. In surface water, zinc is readily transported and is considered one of the most mobile of the heavy metals. This is because complexes of zinc with common ligands in surface water are soluble in neutral and acidic

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solutions. Plants and most fish primarily would be affected by dissolved zinc, but it is possible, depending upon eating habits, that some invertebrates and fish could be affected by ingestion of suspended particulate zinc as well. In freshwater tissues, zinc has been found to bioaccumulate from 50 to 1,130 times the concentration present in water (USEPA 1987a).

Terrestrial plants tend to take up 1% to 3% of zinc added to soil (CH₂M Hill 1986). Most plant species are relatively tolerant to excessive amounts of zinc. Symptoms of zinc toxicity include stunted growth, reduced yields, reduced leaf size, necrosis of leaf-tips, and curled distorted foliage. Zinc concentrations of 0.43 percent to 10.16 percent in acidic soil were found to be toxic to several vegetable crops (Gough et al. 1979). Excessive levels of zinc retard growth in plants by inhibiting root development through restraint on both cell division and elongation (USEPA 1987a).

Zinc toxicity to animals does not normally result from the consumption of ordinary foods. Animals are tolerant of zinc levels 100 times their normal diet requirements (National Research Council (NRC) 1979). In dietary experiments with rats and pigs, intake of 1,000 to 2,500 ppm caused no ill effect; 2,500 to 8,000 ppm caused severe growth depression and anemia; and intake of 8,000 to 10,000 ppm caused high mortality in experimental animals (Gough et al. 1979).

Signs of zinc toxicity in animals include gastrointestinal distress, decreased food intake, decreased growth, anemia, poor bone mineralization, damage to the pancreas, arthritis, and nonviable offspring (NRC 1979).

5.4.2 Derivation of Toxicity Reference Values

TRVs were derived for wildlife, plants, and aquatic life using the procedures outlined below.

5.4.2.1 Wildlife

Potential impacts to wildlife at estimated exposure concentrations were evaluated using published toxicological data as presented in Opresko et al. (1994) for mammalian and avian species. From these data, a toxicity benchmark value (TBV) was chosen for each endpoint species. The TBVs for COPCs at the P11/P13 and A12/P36/P37 sites are provided in Opresko et al. (1994).

Uncertainty arises when using any published TBV to estimate toxicity to wildlife and includes the following:

- Establishing dose equivalency for organisms of varying body size;
- Extrapolating from acute or subchronic exposures to chronic exposure durations:
- Extrapolating from chronic LOAEL to chronic NOAEL; and

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Extrapolating across different species, genera, orders, and families.

The uncertainty factors and scaling factors associated with each of these extrapolations are provided in Opresko et al. (1994). For each endpoint species and COPC, the TRV was obtained from values presented in Opresko et al. (1994), or calculated according to their methods. These values are presented in the ecological risk assessment for each site.

In the case of zinc, an adjustment was made to the NOAELs calculated for mammalian and avian receptors. A UF of 100 was used to derive avian NOAELs and a UF of 10 was used to derive mammalian NOAELs by Opresko et al. (1994). These UFs were judged to be overly conservative, however, based on a review of values for zinc toxicity to wildlife presented in Eisler (1993). Therefore, the experimental values presented for test species by Opresko et al. (1994) were used as TRVs, without adjusting for these overly conservative uncertainty factors.

In the case of the raccoon, NOAELs were calculated following Opresko et al. (1994) by adjusting for differences in body size between the raccoon and the test species:

$$NOAEL_R = NOAEL_T \times (BW_T/BW_R)^{1/3}$$

Where:

 $NOAEL_R$ = No observed adverse effect level for the racoon (mg/kg/d);

 $NOAEL_T$ = No observed adverse effect level for the test species (mg/kg/d);

 BW_R = Body weight of the raccoon (kg);

BW_T = Body weight of the test species (kg).

5.4.2.2 Terrestrial Plants

The TRV used to evaluate phytotoxicity of a given inorganic chemical was the minimum of the range of concentrations considered phytotoxic by various authors (Kabata-Pendias and Pendias 1992). These values are provided in the ecological risk assessment for each site.

5.4.2.3 Aquatic Life

EPA Ambient Water Quality Criteria (AWQC) or other criteria were used as TRVs to assess potential risks to aquatic organisms. AWQC are non-regulatory values based on scientific assessment of ecological effects. They are developed using toxicity data for standard common species with the intent to protect 95% of all aquatic species. AWQC are

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expressed as acute and chronic criteria. Acute AWQC address average toxicant concentrations over 1-hour periods, whereas chronic AWQC address average toxicant concentrations over 4-day periods. Neither acute nor chronic AWOC are to be exceeded more than once every 3 years on average. The AWQC for the COPCs identified at the P11/P13 and A12/P36/P37 sites are provided in the ecological risk assessments for each site.

To assess potential impacts to benthic organisms, published sediment criteria were used as TRVs. Sediment criteria for some organic compounds have been developed by EPA based on the equilibrium partitioning (EP) approach. The EP approach is based on the assumption that partitioning of neutral organic contaminants between particulate sediment and interstitial water phases is controlled by the organic content of the sediment, and toxicity and accumulation of contaminants by benthic organisms is related principally to interstitial water concentrations (USEPA 1993e).

No EPA criteria exist for metals in sediments. However, the Ontario Ministry of Environment has published guidelines for evaluation of sediment contamination (Persaud 1993). These are not legally enforceable in the United States, but they can serve as guidelines to identify potential ecological impacts to sediment-dwelling organisms. Sediment guidelines have also been published by NOAA (Long and Morgan 1991) and others (for a review, see Bennett and Cubbage 1991).

5.4.3 Field Investigations

Limited field studies were conducted to evaluate potential ecological effects of COPCs at the P11/P13 and A12/P36/P37 sites. For all of the sites, evidence of plant or animal stress that may be a result of site contamination was noted by biologists during the ecological field surveys (see the individual ecological characterizations and risk assessments for each site). In addition, rapid bioassessment of macroinvertebrate communities was conducted in Honey Brook and Marlboro Brook.

5.5 RISK CHARACTERIZATION

In this section of each of the individual ecological risk assessments, risks posed by the COPCs at the P11/P13 and A12/P36/P37 sites are identified and summarized. Risk characterization involves two major steps: risk estimation and risk description (USEPA 1992). These steps are described below.

5.5.1 Risk Estimation

The risks of site contamination were estimated by calculating an HQ for each COPC and pathway. The HQs were calculated as follows:

HO = EE/TRV

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where:

HQ = Hazard Quotient

EE = Estimated Exposure

TRV = Toxicity Reference Value

The estimated exposures were derived in the exposure assessment and were based on either the maximum detection of a chemical (RME case) or the average concentration (average exposure case). TRVs were derived in the ecological effects assessment.

An HQ greater than 1 would be considered presumptive evidence for a potential risk of adverse chronic effects of a chemical on a given ecological receptor for a given case, a given pathway, and a given critical effect.

5.5.2 Risk Description

Risk description involves summarizing risks and uncertainties of the ecological risk assessment. In addition, the ecological significance of the risks is discussed. A weight-of-evidence approach was used to determine if the risks predicted using calculation methods are indicative of impacts to individuals, populations, communities, or ecosystems. The spatial and temporal scale of contamination was considered, along with corroborating evidence from field investigations.

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6. IDENTIFICATION OF BACKGROUND LEVELS

The results of previous background and facility-wide sampling conducted by OHM, Dames and Moore, and other USAEC contractors, are not presented or discussed in Chapter 6. While OHM did collect background soil samples as part of previous investigations, the E & E background soil samples were collected from locations determined through consultation with the Annex, regulators, and local community representatives. Thus, the E & E background soil sample locations were more likely to represent more broadly accepted characterizations of background soil conditions. OHM did not collect background surface water or remedial samples. The following sections discuss the background samples E & E collected during the field investigations in 1993. E & E collected surface water, sediment, and surface soil samples to profile natural or background conditions for the entire Annex. Two wells (E3-P13-M03 and E3-P36-M01) were installed, one at each RI site, to characterize local background groundwater quality in the area immediately upgradient of the RI sites.

6.1 BACKGROUND SURFACE SOIL SAMPLING LOCATIONS

Ten background surface soil locations, E3-BCK-S01 through E3-BCK-S10, were chosen after consultation with four town representatives of Families Organized to Clean-Up Sites (FOCUS), MDEP, EPA, Fort Devens EMO, and USAEC representatives. The locations were selected to represent the natural regional soil conditions (background conditions) and were used to assess the impact, if any, of sites at the Annex on the local surface soils. During the collection of the initial background surface soil samples, representatives from the EPA and Fort Devens EMO were present to witness the choice of specific locations and the sampling procedures. Surface soil sample locations are included on Figure 6-1. Sample locations follow:

- Sample (at E3-BCK-S01) was collected on 21 September 1993, near Green Meadow School just north of the Annex in Maynard. It was located 30 feet east of a footpath in a forested area approximately 300 feet southwest of the school buildings.
- Sample (at E3-BCK-S02) was collected on 21 September 1993, near Maynard High School located northeast of the Annex. The sample was taken from a forested area west of the school building and west of a soccer field.
- Sample (at E3-BCK-S03) was collected on 21 September 1993, within the property line of the Maynard Town Cemetery northeast of the Annex. The sample was taken in an relatively undisturbed area in the southern part of the cemetery.

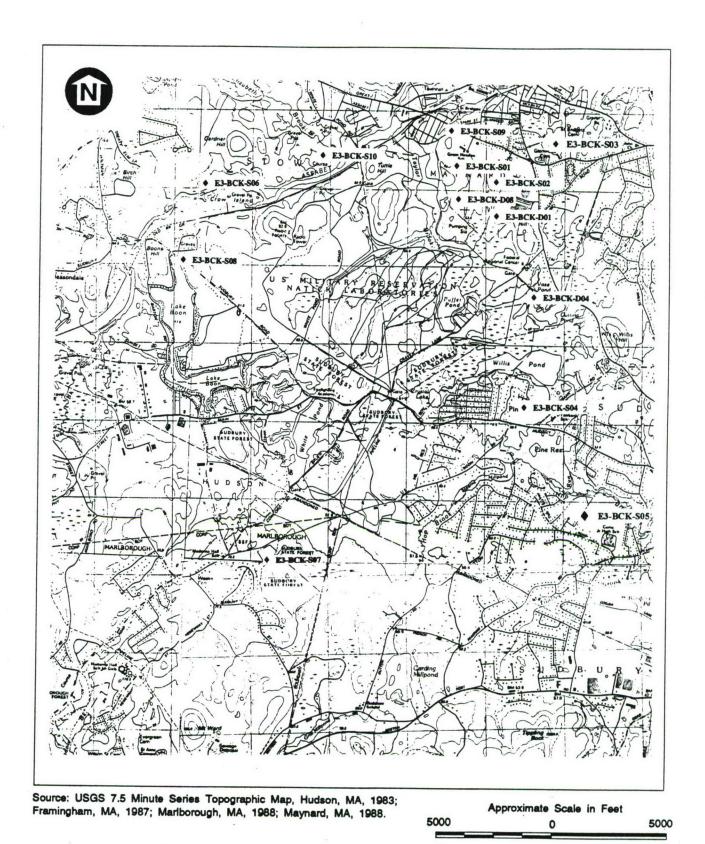


Figure 6-1 BACKGROUND SOIL, STREAM SEDIMENT, AND STREAM WATER SAMPLE LOCATIONS AT THE SUDBURY ANNEX

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 Sample (at E3-BCK-S04) was collected on 21 September 1993, near the Sudbury-Atkinson Pool and Recreation Center southeast of the Annex. The sample was taken from a forested area approximately 1,200 feet north of Hudson Road.

- Sample (at E3-BCK-S05) was collected on 21 September 1993, east
 of the Annex near Hop Brook, on the Curtis Middle School grounds.
 The sample was taken in a forested area located approximately 400
 feet north of the school's baseball field.
- Sample (at E3-BCK-S06) was collected on 22 September 1993, northwest of the Annex at the Crow Island Glider Field. The sample was taken from a forested area in the southwestern edge of the island.
- Sample (at E3-BCK-S07) was collected on 23 September 1993, in the Marlborough State Forest in Marlborough. The sample was taken in a forested area approximately 400 feet southeast of Concord Road, across from the Marlborough Country Club golf course.
- Sample (at E3-BCK-S08) was collected on 23 September 1993, near Pine Bluff's Beach within a public park west of the Annex. The sample was taken approximately 700 feet south of the dirt access road and 400 feet east of Lake Boon.
- Sample (at E3-BCK-S09) was collected on 23 September 1993, near the John A. Crow Maynard Town Park located north of the Annex in Maynard. The sample was taken in a forested area located approximately 500 feet north of a soccer field and tennis courts.
- Sample (at E3-BCK-S10) was collected on 23 September 1993, from an area within the Stow Away Public Golf Course located north of the Annex across the Assabet River. The sample was taken from a relatively undisturbed and forested area located north of the Assabet and approximately 400 feet west of the green for Hole No. 9.

Background soil samples were analyzed for pesticides/PCBs, TAL metals, herbicides, and organophosphates. Analysis of the 10 background soil samples showed consistent levels of metals. Low concentrations of pesticides were found in many of the soil samples, including α -BHC, α -chlordane, β -BHC, β -endosulfan, δ -BHC, dieldrin, endrin, endrin aldehyde, endosulfan sulfate, γ -chlordane, heptachlor epoxide, lindane, and DDT and its degradation products, DDD and DDE. The detection of these pesticides in background soils is in accordance with general pest management practices in the past involving the applications of pesticides in the communities surrounding the Annex, and the pesticide ranges were considered to be valid "background" levels. The sample results for inorganic analytes were statistically analyzed to remove any outliers. The only outlier removed was an arsenic concentration found in one sample at 17 μ g/g. The background soil results for inorganic

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analytes were also compared to concentration ranges for uncontaminated soil of the eastern United States and all inorganics were found within the ranges, usually toward the low end. This suggests that comparing analytes in site soil samples to the highest of the background levels is a sensitive method for identifying site-related contaminations. Table 6-1 lists the highest concentrations of each analyte found in background surface soils. These levels were used for comparison purposes in the RIs. A discussion of the statistical analysis of background soil data for the Annex is presented in Appendix J, along with the full background soil sample data, and a table of concentration ranges for inorganic analytes for soil in the eastern United States.

6.2 BACKGROUND STREAM SURFACE WATER AND SEDIMENT SAMPLING

Three background surface water samples were collected in streams that drain onto the Annex in order to characterize natural background surface water levels for comparison with surface water sampling results at the Annex. Three sediment samples were collected in conjunction with each surface water sample to characterize background sediment conditions for streams at the Annex. These sample locations are noted on Figure 6-1, and are described below:

- The first surface water/sediment sample (at E3-BCK-D01) was collected on 15 September 1993, from the headwaters of a stream south of the parking lot located at the Digital Equipment Corporation (DEC) facility in Maynard. Subsequent analytical results indicated that this sample contained elevated levels of PAHs and lead, likely from the runoff from the parking lot. Although this stream does flow onto the Annex and enters Taylor Brook, it was decided that the presence of PAHs and lead from an off-site anthropogenic source might not represent background conditions for all portions of the Annex. Consequently, the samples collected at this location were not used to establish background levels for the Annex.
- The second surface water/sediment sample (at E3-BCK-D04) was collected on 17 September 1993, from the outlet of Cutting Pond at the eastern boundary of the Annex. This stream drains onto the Annex, and ultimately enters Puffer Pond.
- The third surface water/sediment sample (at E3-BCK-D08) was collected on 21 September 1993, from an unnamed tributary to Taylor Brook located near the northeastern boundary of the Annex and east of Site P45. Although located inside the Annex boundary, this location is upgradient of any sites or any identified area of activity at the Annex.

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Table 6-1
BACKGROUND SOIL SAMPLES
MAXIMUM ANALYTE CONCENTRATIONS

Analytes	Concentration (μg/g)
TAL Metals	
Aluminum	10,400
Antimony	< 0.500
Arsenic	10
Barium	25.1
Beryllium	0.446
Cadmium	< 0.500
Calcium	1,170
Chromium (total)	14.2
Cobalt	6.13
Copper	10.7
Iron	12,300
Lead	150
Magnesium	2,310
Manganese	95.8
Mercury	0.318
Nickel	10.7
Potassium	617
Selenium	0.571
Sodium	<200
Vanadium	33
Zinc	44.6

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Table 6-1 (continued)

BACKGROUND SOIL SAMPLES MAXIMUM ANALYTE CONCENTRATIONS

MAXIMOM ANALTE C	ONCENTRATIONS
Analytes	Concentration (μg/g)
Pesticides/PCBs	
alpha-BHC	0.004
alpha-Chlordane	0.004
beta-BHC	0.002
beta-Endosulfan	0.004
delta-BHC	0.010
Dieldrin	0.023
Endrin	0.008
Endrin Aldehyde	0.011
Endosulfan sulfate	0.008
gamma-Chlordane	0.005
Heptachlor Epoxide	0.006
Lindane	0.001
DDD	0.063
DDE	0.139
DDT	0.230

Source: Ecology and Environment, Inc. 1994.

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Summary of Background Stream Surface Water Analysis

Background surface water samples were analyzed for TCL volatile organics. TCL BNAs, TCL pesticides/PCBs, TAL metals, explosives, TPHC, and phosphate. As noted above, the background samples taken in the drainage located downstream of the DEC facility were not used to establish background surface water or sediment levels for the Annex. The higher of the results of laboratory analysis for the other two surface water samples was used as a screening tool to evaluate potential contamination of surface waters at the Annex. Given that there were only two background surface water samples considered, no statistical analysis was performed to remove outliers. One result of note in the background surface water samples was the detection of low levels of PCE (1.90 μ g/L, estimated) and TCE (1.80 μ g/L, estimated) at levels below the reporting limit in one of the background streams (at E3-BCK-D08). While these compounds were not found in trip blanks in the field or in method blanks, it is unlikely that there is a source of these compounds in this stream, and they are considered to be laboratory artifacts. The results for PCE and TCE were not used to establish background surface water levels for the Annex. The highest levels of compounds found in background surface water samples (except PCE and TCE) are listed in Table 6-2. The complete data set for background surface water samples is presented in Appendix J.

Summary of Background Stream Sediment Analysis

Background sediment samples were analyzed for TCL VOC, TCL BNAs, TCL pesticides/PCBs, TAL metals, explosives, TPHC, and TOC. Given that there were only two sediment samples considered appropriate to establish background sediment levels, no statistical analysis was performed to remove outliers. Pesticide concentrations found in the background sediment samples, like in the background surface soils, probably reflect earlier pesticide use in past in the general area, and were considered valid "background" levels for comparison purposes. TPHC (16.6 μ g/g) was found in the sediment sample taken from the Cutting Pond outlet, possibly indicating some low-level runoff from the surrounding off-Annex area. The two background sediment samples were collected from hard rock streams with very little organic matter, and this is reflected in the low TOC content of these samples, which ranges from 7,690 μ g/g to 14,200 μ g/g. Organic-rich sediments naturally contain higher concentrations of inorganic analytes due to their greater sorbing capacity. Thus the background stream sediment samples may underrepresent the actual "natural" range of inorganic analytes for samples that contain higher amounts of organic material. In a similar way, organic-rich sediments can also contain higher concentrations of organic compounds like pesticides from general pest management practices. Thus, in order to provide appropriate background comparisons for analytical data for the five sites discussed in the two RIs in this report, sediment analytical data were compared to the stream sediment background levels in all cases, and was additionally compared to the background pond sediment background levels (see discussion Section 6.3 below) when TOC content was greater than 10 percent. The background pond sediments were relatively organic-rich (TOCs ranging from 336,000 µg/g to 577,000 μ g/g) and are felt to be appropriate background comparison references for organicrich sediments found in pond areas or wetlands at the Annex. The highest concentrations of analytes found in background stream sediment samples are listed in Table 6-2. The complete data set for background stream sediment samples is presented in Appendix J.

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Table 6-2
BACKGROUND STREAM SAMPLES
MAXIMUM ANALYTE CONCENTRATIONS

Analyte	Sediment (µg/g)	Water (µg/L)
TAL Metals		
Aluminum	5,020	400
Antimony	<0.5	<5
Arsenic	2.03	3.15
Barium	23.9	10.4
Beryllium	0.18	<5
Cadmium	<0.5	<5
Calcium	562	8,520
Chromium (total)	9.66	3.16
Cobalt	3.74	4.79
Copper	6.33	<10
Iron	7,590	4,810
Lead	4.48	10.3
Magnesium	2,140	1,890
Manganese	70.5	156
Nickel	5.92	<10
Potassium	1,520	2,060
Selenium	0.2	<2
Sodium	<200	14,000
Thallium	0.195	ND
Vanadium	17	4.72
Zinc	20.8	13.3
TPHC Total Petroleum Hydrocarbons	16.6	ND
Pesticides/PCBs		
Aldrin	0.007	ND
Endosulfan sulfate	0.001	ND
Lindane	0.001	ND
Phosphorus	NA	280

Key: ND = Not Detected NA - Not analyzed

Source: Ecology and Environment, Inc. 1994.

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6.3 BACKGROUND POND SURFACE WATER AND SEDIMENT SAMPLING

In order to establish baseline data for the study of site-related contamination in Puffer Pond, a background study was conducted at Ministers Pond. The selection of Ministers Pond as background was based on the criteria established by the MDEP, specifically, the reference location should have no or minimal potential for impacts; a central Massachusetts location; and similar morphology. Both Puffer Pond and Ministers Pond are shallow, mesotrophic to eutrophic ponds with tannic waters, a comparatively low pH, and extensive wetlands adjacent to them. The ponds have similar drainage and are part of the Assabet River drainage. Ministers Pond is located in the town of Stow, approximately one mile northwest of the Annex. The study was designed to determine background levels of pesticides and metals in the area. Therefore, sediment samples were analyzed for pesticides, organophosphorus pesticides, TAL metals, and TOC. Surface water samples were analyzed for pesticides, organophosphorus pesticides and TAL metals. Samples were collected on 9 November 1993, using a sample container for the surface water and a dredge for sediment. Six of each were collected. The sample locations are designated as E3-OFF-D01 through E3-OFF-D06. Inorganic analytes in Ministers Pond surface water and sediment samples were statistically analyzed to remove any outliers. Surface water samples were found to contain metals but no detectable levels of pesticides. Sediment samples contained metals and the DDT degradation products DDD and DDE. The DDD and DDE concentrations probably reflect past pesticide applications in the vicinity or upstream of Ministers Pond. The highest concentrations of analytes in Ministers Pond sediments were used as comparison levels for the surface water and sediment results from Puffer Pond and are listed in Table 6-3. As noted above, the background pond sediment levels were also used for comparison to organic rich sediments (assumed for this report to have TOC content greater than 10 percent) from pond and wetland areas at the sites discussed in this report. The complete data set for sediment sampling at Ministers Pond are presented in Appendix J along with comparison data for sediment in remote New England lakes.

6.4 LOCAL BACKGROUND GROUNDWATER SAMPLING

At each of the two RI locations, one monitoring well was installed to characterize the background groundwater quality at a point immediately upgradient of any potential contaminant sources. For the P11/P13 RI, the upgradient local background well is E3-P13-M03. For the A12/P36/P37 RI, the upgradient local background well is E3-P36-M01. Review of all available geophysical, historical, and hydrogeological information for those sites identifies that these well locations are in areas hydrogeologically upgradient of potential sources identified at these sites. The details of installation of these two local background wells are described in Section 2 of Volumes II and III for each RI location. The groundwater flow assessment to support these conclusions are presented in Section 3 of Volumes II and Volume III for each RI location. Finally, the analytical results of groundwater sampling of each of these local background wells are discussed in Section 4 of Volume II and III for each RI location and the summary chemical results are presented in tables at the end of Section 4 in both RI reports.

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Table 6-3	
BACKGROUND POND SAMPLES (MINISTERS POND) MAXIMUM ANALYTE CONCENTRATIONS	
	4

Analyte	Sediment (μg/g)	Water (µg/L)
TAL Metals		
Aluminum	5,740	69.2
Antimony .	<0.5	<5
Arsenic	9.56	<2
Barium	55.3	14
Beryllium	<0.5	<5
Cadmium	2.06	<5
Calcium	4,550	8,730
Chromium (total)	12.8	<10
Cobalt	11.4	2.32
Copper	10.9	<10
Iron	16,300	1,110
Lead	49.4	3.02
Magnesium	1,480	2,250
Manganese	74.1	26.6
Nickel	23.2	11.3
Potassium	900	3,640
Selenium	<0.2	<2
Silver	0.879	ND
Sodium	778	18,000
Thallium	<0.5	ND
Vanadium	21.8	10
Zinc	55.3	67.8
Pesticides/PCBs		
ODD	0.39	ND
DDE	0.074	ND
ODT	< 0.01	ND

Key:

ND = Not Detected

Source: Ecology and Environment, Inc. 1994.

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7. IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

As specified in CERCLA, remedial actions for cleanup of hazardous substances must comply with applicable or relevant and appropriate requirements (ARARs) of all other Federal, State, and local environmental statutes. At the Annex, these statutes include those established by EPA and other Federal agencies, and those established by the Commonwealth of Massachusetts when the State standards are more stringent than the Federal standards. The Federal facilities provisions of the Superfund Amendments and Reauthorization Act (SARA) state that the same environmental guidelines, rules, criteria, and regulations that apply to non-Federal facilities also apply to Federal facilities.

Applicable requirements are defined in 52 FR 32496 as:

those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site.

Relevant and appropriate requirements are defined in 52 FR 32496 as:

those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Requirements may be either applicable or relevant and appropriate but must be both relevant and appropriate for compliance to be deemed necessary.

Under CERCLA regulations, response actions at the Annex must comply with substantive requirements of other environmental laws, but not with their specific administrative requirements. Substantive requirements include cleanup standards and levels of control, while administrative requirements include permitting and reporting processes. The EPA states in the NCP that administrative requirements are to be accomplished through State, local, and public involvement in the CERCLA process. Therefore, the goal of CERCLA regulations is to complete comprehensive and timely cleanups of the sites, utilizing all substantive requirements in existence, without requiring the repetition of administrative permitting processes for Federal and State environmental statutes.

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In addition to the legally binding ARARs, many Federal and State programs have developed less formal criteria, advisories, guidelines, or proposed standards that are to be considered (TBC) in CERCLA investigations. These TBCs are not legally enforceable, but they provide guidance for evaluating the site-related contamination for cases where ARARs do not exist. TBC criteria will be included throughout the ARAR discussion and will be used to develop remedial action levels, where ARARs do not exist.

In practice, ARARs are separated into three categories; chemical-specific ARARs, location-specific ARARs, and action-specific ARARs, all of which are reviewed in the following sections. This section is a limited summary of all ARARs identified by Oak Ridge National Laboratories presented in Appendix I. The ARARs have been summarized to provide a brief review of regulations or regulatory levels which may apply to the specific sites at the Annex. For a more detailed description and listing of ARARs and how they were derived, refer to Appendix I.

7.1 CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs are usually health- or risk-based numerical values, or are derived from methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values are the legally acceptable concentration of a chemical that may remain in, or be discharged to an ambient medium. Chemical-specific ARARs for the Annex which have been developed for the sites at the Annex by Oak Ridge National Laboratories are provided in Appendix I and are summarized below. Some ARARs discussed by Oak Ridge, such as the Safe Drinking Water Act (SDWA) Action Levels, also were already defined under another regulation. There were no chemical-specific ARARs identified for sediments under Federal or Massachusetts law.

7.1.1 Groundwater

The following chemical-specific ARARs were identified by Oak Ridge National Laboratories which apply to groundwater analytes detected at the Annex.

EPA SDWA Maximum Contaminant Levels (MCLs) are promulgated by the EPA's Office of Drinking Water and are enforceable standards that apply to contaminants found in public water systems that have at least 15 service connections or serve an average of at least 25 people daily at least 60 days of the year. MCLs are enforceable standards that take into consideration human health effects, available treatment technologies, and costs of treatment. MCLs would be legally applicable to remediation of any Zone II groundwater or of groundwater that serves a public water supply well. MCLs are set as close as feasible to Maximum Contaminant Level Goals (MCLGs), which are non-enforceable, health-based goals at which no known or anticipated adverse effects on health will occur. MCLGs are derived without regard to the cost or treatment feasibility. The MCLGs are not legally enforceable, but would be relevant and appropriate for cleanup of groundwater.

National Secondary Drinking Water Regulations have also been established under the SDWA in 40 CFR Part 143. The secondary standards, known as SMCLs, are levels

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established to regulate the aesthetic qualities related to public acceptance of drinking water. These Federal regulations are not enforceable, and are TBC guidance only.

The Commonwealth of Massachusetts has adopted Drinking Water Standards and Guidelines, expressed in terms of maximum levels of contaminants allowable in drinking water. Oak Ridge National Laboratory identified the Massachusetts Maximum Contaminant Levels (MMCLs) as applicable requirements for remediation of medium- to high-yield groundwater that could be a potential source of drinking water supply. The MMCLs are identical to the SDWA MCLs, with the exception of chlordane, for which the SDWA MCL of 2 μ g/L is stricter than the MMCL of 5 μ g/L. Massachusetts Secondary MCLs have been promulgated as well, pursuant to 310 CMR Section 22, and are identified by Oak Ridge as relevant and appropriate for cleanup of groundwater but are based on aesthetic considerations of taste and smell or the staining effects of the water, not on health risks. Massachusetts also presents Groundwater Quality Standards in 314 CMR 6.00.

The Commonwealth of Massachusetts also has established Groundwater Standards in the Massachusetts Contingency Plan (MCP). These standards apply to the cleanup of disposal sites and are developed using a Method 1 risk characterization approach (310 CMR 40.0970), which compares the current and reasonably foreseeable use of the groundwater at the disposal site to promulgated standards. Category GW-1 groundwater is defined as one of the following: within a Zone II area, within a Wellhead Protection Area, within a potentially productive aguifer, within Zone A of a Class A surface water body, within 500 feet or more of a public water system distribution pipeline, or within 500 feet of a private water supply well. A Zone II area is defined as groundwater that contributes water to wells pumping greater than 100,000 gallons per day. A GW-2 classification refers to groundwater nearby a building and is primarily concerned with vapors entering the building, and a GW-3 classification is primarily concerned with groundwater discharging to surface waters that are not a potential source of drinking water. Based on these definitions, certain areas of groundwater at the Annex would be in Category GW-1 and certain areas would be in Category GW-3. Given the low yield aquifers at the two RI sites, and the distance from the sites to private wells, both sites are likely to have GW-3 category groundwater. The MCP Method 1 groundwater standards provided for the GW-1 category were the most conservative of the groundwater categories for contaminants found at the Annex.

The EPA Office of Water has published Lifetime Drinking Water Health Advisory (HA) values based on 10⁻⁶ cancer risk levels. These values are calculated assuming that individuals receive 80 percent of their exposure from sources other than consumption of drinking water. These HA values are TBC guidance for groundwater at the Annex.

The MDEP Office of Research and Standards issues *The Office of Research and Standards Guidelines* (ORSG) for chemicals for which MMCLs have not been promulgated. These guidelines apply to non-chlorinated water supplies and represent a level at or below which adverse, non-cancer health effects are unlikely to occur. The ORSG are based on an excess lifetime cancer risk of less than or equal to one in one million. SDWA MCLs that have been promulgated by EPA but are not yet effective are listed as ORSGs and are TBC guidance for groundwater at the Annex.

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7.1.2 Soil

The following Chemical-Specific ARARs have been identified by Oak Ridge National Laboratories and E & E as applicable to soils for the analytes detected at the Annex.

There are currently no set maximum allowable residual levels for chemicals in soils under Federal law.

The Commonwealth of Massachusetts has established soil standards in the MCP. Categories of groundwater and soil have been established by the MDEP as part of the MCP for risk characterization. The MCP uses both groundwater and soil categorization to establish risk characterization levels for soils. The most conservative soil standards for the analytes detected at the Annex are for areas where groundwater may be used for drinking water (category GW-1) with the exception of Benzo[G,H,I]perylene, which had a more conservative value of 30 μ g/g under GW-3 classification. Soil levels of S-1, S-2, and S-3 are based on the frequency or intensity of use and the accessibility of a child's or adult's exposure to the soil, as categorized in Table 7-1. The MCP standards for soils are established following the MCP Method 1 risk characterization approach. MCP Method 2 provides formulas for deriving standards specific to the sample point conditions, and Method 3 provides an approach for calculating standards through a risk assessment. The MCP soil levels are provided in Appendix I.

For sites contaminated by PCBs, A Guide on Remedial Actions at Superfund Sites with PCB Contamination (USEPA 1990a) proposes maximum recommended surface soil levels of 10 μ g/g for unrestricted access industrial sites, 25 μ g/g for restricted access industrial sites, and 1 μ g/g for sites in residential areas; these levels will be used as guidance for remediation, as well as risk based concentrations from the Human Health Risk Assessment.

E & E identified the EPA Region III risk-based concentrations (RBCs) as TBC guidance when no MCP value for soil existed. The RBCs are based on published reference doses, cancer potency slopes, "standard" exposure scenarios (i.e., an adult body weight of 70 kg, a child body weight of 15 kg for ages 1 to 6, and a daily soil ingestion rate of 100 mg for adults and 200 mg for children). The concentrations reported correspond to a hazard quotient of 1, indicating either no risk of non-carcinogenic effects, or a lifetime cancer risk of one in one million, whichever is lower. The EPA Region III risk-based soil concentrations are designed as a screening tool, and this approach "has no official status as either regulation or guidance, and should be used only as a predictor of generic-single-contaminant health risk estimates" (USEPA 1994a). A list of EPA Region III RBCs is included in Appendix I.

E & E also identified the EPA Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities screening level of 400 μ g/g (USEPA 1994b) as an ARAR to replace the earlier EPA interim guidance levels of 500 μ g/g.

			Table 7-1	7-1				
SOIL		CATEGORY SELECTION MATRIX — HUMAN EXPOSURE POTENTIAL	N MATRIX	- HUMA	N EXPOSU	RE POTENTI	IAL	
			R	eceptor Ch	Receptor Characteristics	10		
		Children Present	Present			Adults ONLY Present	Present	
	High	High Frequency	Low Frequency	quency	High I	High Frequency	Low Frequency	equency
Accessibility ↓ of Soil ↓	High Intensity	Low Intensity	High Intensity	Low Intensity	High Intensity	Low Intensity	High Intensity	Low Intensity
Accessible (Surficial) Soil $0 \le 3$, (unpaved)		CATEGORY S-1*	S-1*	S-2	S-1	CATEGORY S-2	RY S-2	
Potentially Accessible Soil 0 \le 3' (paved) - or - 0 \le 15' (unpaved)	-	CATEGORY S-2	RY S-2		S-2			
Isolated Subsurface Soils > 15' or under the footprint of a building or permanent structure	-	CATEGORY S-3	RY S-3			CATE	CATEGORY S-3	£.
* Category S-1 also applies to any ac vegetables for human consumption.	o applies to any ıman consumptio	* Category S-1 also applies to any accessible soil where the current or reasonably foreseeable use of the soil is for growing fruits and vegetables for human consumption.	ere the current	t or reasonably	y foreseeable u	se of the soil is fo	or growing fru	iits and

Source: MCP document 310 CMR 40.000 Table 40.933 (9).

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7.1.3 Surface Water

The following chemical-specific ARARs were identified for surface water by Oak Ridge National Laboratories for the analytes detected at the Annex.

Massachusetts has adopted the Clean Water Act (CWA) AWOC as the Massachusetts water quality criteria (WQC). The Massachusetts WQC could be considered applicable for the remediation of contamination in the on-site surface water bodies which are considered Class B waters. The Annex is within the Concord River Basin, which has a Class B waterway classification. Oak Ridge identified Puffer Pond, Willis Pond, Cutting Pond and Vose Pond, in addition to the Assabet River, as Class B waters. The EPA has developed AWQC for the protection of human health and aquatic life. AWQC for the protection of human health are divided into two separate categories: one for the protection of human health from risks due to water and fish consumption, and a second for the protection of human health from risks due solely to the consumption of fish. AWQC for the protection of human health from risks due both to water and fish consumption can be several orders of magnitude lower than those for the protection from risks of fish consumption alone. AWOC for human health are based on a 10⁻⁶ risk level.

EPA has also developed AWQC for the protection of all life stages of aquatic animals and plants. These criteria specify the contaminant concentration in ambient surface water that, if not exceeded, should protect most species of aquatic life. The chronic criterion represents the contaminant concentration that should not be exceeded by the four-day average chemical concentration more than once every three years. In developing a chronic AWOC, EPA estimates protective contaminant levels based on chronic toxicological data for animals, plants and on residue level in aquatic organism. The acute criteria represents the level that should not be exceeded by the one-hour average concentration more than once every three years.

The Massachusetts/CWA AWQC values are discussed in further detail and listed in Appendix I.

7.2 LOCATION-SPECIFIC ARARS

Location-specific ARARs select criteria specific to the settings of the Annex, considering factors such as local geological hazards, hydrologic settings, special natural resource areas, and archaeological and historic resources. A detailed analysis of the locationspecific ARARs for the sites at the Annex prepared by Oak Ridge National Laboratories is provided in text and tabular form in Appendix I and a limited summary is provided below.

No site-specific geologic hazards such as faults, caves, salt domes, or bed formations which would trigger location-specific ARARs were identified at the Annex. Wetlands occur throughout the Annex, and any remediation activities would be subject to requirements under Federal and Massachusetts law which protect these resources against any adverse effects caused by a remediation technology developed in the FS, if an FS is required. Any activity involving control of a natural stream would be subject to the Fish and Wildlife Coordination

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Act. Discharging dredge or fill material into an aquatic ecosystem would be subject to the CWA. Although no endangered species have been identified at either of the two RI sites, rare, threatened, and endangered species habitats have been documented at the Annex, and any disturbance of them is regulated under the Endangered Species Act.

Although no historic or archaeological resources have been identified at either of the two RI sites, archeological surveys have indicated that resources may be present at the Annex. Such resources would be protected under State and Federal law, including the Archaeological and Historic Preservation Act and the National Historic Preservation Act. When remedial actions are considered, contingencies to further identify and respond to these resources under the regulations of location-specific ARARs will be developed in the FS, if an FS is required.

7.3 ACTION-SPECIFIC ARARS

Action-specific ARARs are technology- or activity-based requirements or limitations on actions taken with respect to remediation of contamination. These requirements are triggered by the particular remedial activities selected to accomplish a remedy, and indicate how a selected alternative must be achieved. Action-specific requirements will be identified with the development of alternatives in the FS, if an FS is required.

The Federal Resource Conservation and Recovery Act (RCRA) and the State authorized RCRA/21C provide definitions of hazardous wastes, along with regulations governing the treatment, storage, and disposal of hazardous waste. CERCLA sites must incorporate the substantive, but not the administrative, requirements of RCRA in remedial activities. The Toxic Substances Control Act (TSCA) provides additional clean up standards which may be ARARs at the Annex. A detailed analysis of the action-specific ARARs for remedial activities which may occur at the Annex sites will be incorporated into the FS, if an FS is required.

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Sudbury Annex Vol. II

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PREFACE

This is Volume II of a four volume set that comprises the report of the remedial investigations (RIs) conducted at the Sudbury Training Annex of Fort Devens, Massachusetts. Volume I provides general and procedural information common to the RI sites investigated. This volume contains the RI for Site P11/P13. Volume III contains the RI for Site A12/P36/P37.

Volume IV of this report set includes the appendices, which present field notes, drilling logs, geotechnical data, geophysical investigation summaries, analytical qualification results, ecological investigation results, and other data produced during the RIs.

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#### LIST OF ACRONYMS

ABS Absorption Factor Skin

AEHA U.S. Army Environmental Hygiene Agency

 $\alpha$  alpha

AMEL Aero-Mechanical Engineering Laboratory

AMSL Above Mean Sea Level

ARARs Applicable or Relevant and Appropriate Requirements

ASC Analytical Services Center (E & E)

AST Aboveground Storage Tank

AT Averaging Time ATEC, Inc.

ATSDR Agency for Toxic Substances and Disease Registry

AWQC Ambient Water Quality Criteria

BAF Bioaccumulation Factor
BGS Below Ground Gurface
BHC Benzenehexachloride

BNAs Base/Neutral/Acid Extractables

BTEX Benzene, Toluene, Ethylbenzene, and Xylenes

 $\beta$  beta

BW Body Weight

CEMEL Clothing Equipment Material Engineering Laboratory

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act of

1980

CFHA Capehart Family Housing Area

COC Chain-of-Custody

COPCs Contaminants of Potential Concern

CS Concentration in Soil
cm/sec Centimeters per Second
DBH Diameter at Breast Height
DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
DEC Digital Equipment Corporation

 $\delta, \Delta$  delta

DQOs Data Quality Objectives ED Exposure Duration

E & E Ecology and Environment, Inc.

EF Exposure Factor Electromagnetics

EP Equilibrium Partitioning

EPA U.S. Environmental Protection Agency

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EPCs Exposure Point Concentrations ERA Ecological Risk Assessment

ERL Effects-Range Low FC Fraction Contacted

FEMA Federal Emergency Management Agency

FI Fraction Ingested

FID Flame Ionization Detection FIT Field Investigation Team

FOCUS Families Organized to Clean-up Sites

FORSCOM U.S. Army Forces Command

FS Feasibility Study

g Grams

GC Gas Chromatography

γ gamma

GI Gastrointestinal gpm Gallons per Minute

GPR Ground Penetrating Radar
GZA Goldberg Zoino and Associates

HASP Health and Safety Plan

HEAST Health Effects Assessment Summary Tables

HHRA Human Health Risk Assessment

HI Hazard Index HQ Hazard Quotient IR Ingestion Rate

IRDMIS Installation Restoration Data Management Information System

kg Kilogram

MCLs Maximum Contaminant Levels
MCP Massachusetts Contingency Plan

MDEP Massachusetts Department of Environmental Protection

MEK Methyl Ethyl Ketone or 2-Butanone

MEP Master Environmental Plan

MFFA Massachusetts Fire Fighting Academy

MNHESP Massachusetts Natural Heritage and Endangered Species Program

m Meter mg Milligrams

μg/dL Micrograms per Deciliter

ml Milliliter

MOTS Maynard Ordnance Test Station
MQAPjP Master Quality Assurance Project Plan

MRLs Method Reporting Limits

MS/MSD Matrix Spike/Matrix Spike Duplicates

 $\mu g/g$  Micrograms per Gram  $\mu g/L$  Micrograms per Liter

NDIR Non-Disperse Infra-Red Spectroscopy
NERI Northeast Research Institute, Inc.

NFA No Further Action

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NIPDWR National Interim Primary Drinking Water Regulation NOAA National Oceanic and Atmospheric Administration

NPL National Priorities List
NWI National Wetlands Inventory

OHM Remediation Services Corporation, A Subsidiary of OHM Corporation

OVA Organic Vapor Analyzer PA Preliminary Assessment

PAH Polynuclear Aromatic Hydrocarbons or Polycyclic Aromatic Hydrocarbons

PCB Polychlorinated Biphenyl

PCE Tetrachloroethene or Perchloroethene

PID Photoionization Detector

ppb Parts per Billion

PPE Personal protective equipment

ppm Parts per Million

PRD Pioneering Research Division

PX Post Exchange QA Quality Assurance

OAPiP Quality Assurance Project Plan

QC Quality Control

RAF Relative Absorption Factor
RBA Rapid Bioassessment
RBC Risk-Based Concentration

RCRA Resource Recovery and Conservation Act

RfD Reference Dose

RI Remedial Investigation
RME Reasonable Maximum Exposure

RME Reasonable Maximum Expo RPD Relative Percent Difference

SA Skin Area

SAS Special Analytical Services SCS Soil Conservation Service

SI Site Investigation
SM Scanner Magnetrometric
TAL Target Analyte List
TBV Toxicity Benchmark Value
TCL Target Compound List

TEPS Total Environmental Program Support

TOV Total Organic Volatiles

TPHC Total Petroleum Hydrocarbons
TRC Technical Review Committee
TRV Toxicity Reference Values
TSCA Toxic Substances Control Act
TSS Total Suspended Solids

USAEC United States Army Environmental Center

USAF United States Air Force

USATHAMA United States Army Toxic and Hazardous Materials Agency

USDA United States Department of Agriculture

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**USFWS** 

United States Fish and Wildlife Service

UST VOC WHO Underground Storage Tank Volatile Organic Compound

World Health Organization

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Date:

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#### **EXECUTIVE SUMMARY**

The Remedial Investigation (RI) at Sites P11/P13, the Building T405 area and the former Massachusetts Fire Fighting Academy site, of Fort Devens Sudbury Training Annex (the Annex), Massachusetts, was performed by Ecology and Environment, Inc., (E & E) for the United States Army Environmental Center (USAEC) under Total Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012, Delivery Order No. 0004. This volume reports the investigations performed, and the conclusions and recommendations reached.

Site P11 is the area around and including Building T405 where chemicals allegedly were dumped. Site P13 is a series of buildings formerly used by the Army, government research contractors, Massachusetts State Police, the Air National Guard, and the Massachusetts Fire Fighting Academy. Both Sites P11 and P13 are within a cleared and fenced area at the junction of White Pond Road and Puffer Road, and constitute a single contiguous site. Activities performed in the past include well installation and groundwater sampling, a soil gas survey, geophysical surveys, soil sampling, and drum and tank removals. The E & E Site Investigation (SI) included well installation and groundwater sampling, geophysical surveys, an ecological survey, soil sampling, and surface water and sediment sampling. Human health and ecological risk assessments were subsequently performed using SI data to fulfill the requirements of an RI.

The conclusions of the human health risk assessment are that current conditions do not present an unacceptable threat to human health. A slight exceedance of cancer risk to human health occurs under future residential use scenarios using average levels of metals in filtered groundwater (1.8 x 10⁻⁴), but the level of arsenic responsible for this estimated risk is well below the United States Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) established for arsenic in drinking water. Total Hazard Indices (HIs) for average exposure to filtered (non-turbid) groundwater are less than the EPA benchmark level of 1.0 for both adults and children. It was also concluded that groundwater at the site is not a current or likely future source of drinking water because of the low yield of the aquifer and the presence of an existing public water supply line on site.

Although there are no risk factors approved by the EPA for use in calculating non-cancer risks from the polychlorinated biphenyl (PCB) 1254 and lead, the main contaminants of concern, risks were calculated using Commonwealth of Massachusetts risk factors. These are derived from animal testing data by incorporating a thousand-fold safety margin to ensure that no observable effects occur even in the most sensitive human subpopulation exposed. These calculations resulted in a HI of 15 for children, mainly from dermal adsorption and ingestion of PCB 1254, assuming exposure during an entire childhood to soil containing the level of PCB 1254 found in the most contaminated soil sample from on site.

The maximum level of lead in on-site soils did not exceed half the concentration recommended by the EPA as a screening value for cleanup of residential soils. The ecological risk represented by this site is also minimal.

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The maximum level of PCB in surface soil exceeds the 1.0  $\mu$ g/g EPA screening level for residential soils. It is recommended that the soils be cleaned up to this 1  $\mu$ g/g level before the site is released for unrestricted use.

The risk due to PCBs is caused by a level of less than 50 ppm and compliance with the disposal regulations of the Toxic Substances Control Act (TSCA) is not required. The risk is not sufficient to warrant a formal removal action under CERCLA, but can be handled by a simple administrative action.

It is recommended that a No Action Proposed Plan be prepared for Site P11/P13.

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#### 1. INTRODUCTION

The United States Army Environmental Center (USAEC) tasked Ecology and Environment, Inc., (E & E) to prepare a Remedial Investigation (RI) report for two previously investigated sites (P11/P13) at the Fort Devens Sudbury Training Annex (the Annex) in Maynard, Massachusetts. This report has been prepared under Delivery Order No. 0004 of the Technical Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012.

Site P11 (Building T405 Area) and Site P13 (Massachusetts Fire Fighting Academy (MFFA)) were identified in the initial draft of the Master Environmental Plan (MEP) in 1992 for different potential contaminant concerns. Site P11 was identified in 1990 during interviews with Natick Laboratory employees who identified that the disposal of chemicals used in research at Building T405 may have occurred along the fence west of the building (Interview 1990). Site P13 was identified in a 1990 Fort Devens memorandum as a possible concern due to the suspected contamination that may have resulted from underground storage tanks (USTs), above-ground storage tanks (ASTs), and fire training activities associated with the site area (Fort Devens 1990).

These two sites are located immediately adjacent to each other in the northwestern portion of Watershed 1B (Lower Taylor Brook) in the northwestern part of the Annex. Due to this proximity, a single RI addressing all concerns at the two sites was conducted, which involved evaluating data from the earlier site investigations (SIs) and preparing human health and ecological risk assessments. The term "site" will refer to the entire area encompassed by the two sites unless otherwise designated.

Previous removal actions at the site included UST and AST removals by ATEC, Inc. (ATEC) and Fort Devens personnel in 1992. ATEC removed six USTs from the site: a 1,000-gallon UST at Building T405; a 5,000-gallon UST at Building T406; a 1,000-gallon UST at Building T407; a 1,000-gallon UST at Building T408; a 1,000-gallon UST at Building T409; and a 2,000-gallon UST at Building T410. Removal actions consisted of soil excavations to remove petroleum contaminated soils from locations where the USTs had leaked. In addition to UST removal, several drums were removed from the site and relocated. Fort Devens personnel also removed several ASTs near Buildings T406 and T410.

Previous environmental investigations at the site were conducted by the United States Army Environmental Hygiene Agency (AEHA) and OHM Remediation Services Corporation (OHM). In 1983, AEHA conducted a hydrogeologic investigation and subsurface evaluation. In 1991 and 1992, OHM conducted a SI of the site and its surroundings that consisted of a soil gas survey, a geophysical study, test pit excavations with subsurface soil sampling, monitoring well installation with subsurface soil sampling, groundwater sampling, a hydrogeologic assessment, removal of empty 55-gallon drums, and confirmatory sampling at each drum location.

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E & E conducted an environmental investigation of Site P11/P13 in 1993 and 1994, which included the following: monitoring well installation and development; topographic surveying; ecological field surveying; exploratory pit excavation; groundwater sampling; and surface water/sediment sampling. E & E field activities at this site are discussed in Section 2.

The results of field investigation and sampling efforts were used to describe the physical characteristics of the site (Section 3), and to identify the nature and extent of contamination (Section 4). Based on the profile of sources and existing contamination identified in Section 4, the fate and transport of potential contaminants found at the site were profiled in Section 5. The profile of the nature and extent of contamination was also used to conduct a human health risk assessment (Section 6), and an ecological risk assessment (Section 7). Conclusions drawn from the investigation and risk assessments and recommendations for future action at the site are discussed in Section 8. References cited or consulted in preparing the RI report are included in Section 9. The reader should note that general information about the RI process and investigation procedures are included in Volume I of the report set. Appendices referenced in the text are included in Volume IV of the report set.

#### 1.1 RI LOCATION AND DESCRIPTION

The site is located in the northwestern corner of the Annex, south of the northern intersection of White Pond Road and Patrol Road. Figure 1-2 in Volume I identifies the site location in the Annex. An oversized site map (Plate) based on surveyed 2-foot contours is enclosed in the back of this volume, and displays all the sample points, surface features, and monitoring wells at the site with the exception of two downgradient surface water/sediment sampling locations, which are included on the Plate at the end of Volume I. Figures identifying groundwater contours and flow directions, as well as surface water flow directions at the site, are included in Section 3 of this volume.

White Pond Road is the northwest boundary of the site, while Puffer Road is the northeast boundary of the site. Forested wetland areas are located on the eastern and southeastern boundaries of the site. Forested areas bound the southern and western sides of the site. Currently, eight buildings are on the site, most of which were constructed in 1952. Building T404, formerly a bachelor officers quarters and office, is located on the north edge of the site along White Pond Road. Building T405, a former barricade building for ordnance research and laboratory, is located at the western end of the site. Three styrofoam structures are located west of Building T405; two are located just outside of the fence west of Building T405, and the third is located between the fence and Building T405. The styrofoam structures are very similar to, and are shaped like, igloos or beehives, being semiconical with no floors. Each has an opening in the side. They have circular floor plans and are approximately 4 to 5 feet tall. These structures were simply design experiments and were not used for anything. A concrete pit is located northwest of Building T405 near White Pond Road. A drum was removed by OHM from the area between the two styrofoam structures outside of the fence. On the eastern side of Building T405 is a cesspool and the former

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location of a 1,000-gallon UST. Monitoring wells E3-P11-M01, OHM-P11-32, OHM-P11-33, and OHM-P11-34 are located on the southern, western, eastern, and northern sides of Building T405, respectively.

Building T406, formerly used as a power plant, machine shop, and as a kitchen and mess hall, is located in the center of the site and is bordered on the western side by an access road and on the northern side by a concrete walkway. A 5,000-gallon UST was formerly located between the building and the access road on the western side. A 500-gallon AST was formerly located on the eastern side of the building. Several drums were removed from the area south of this building. Currently, a transformer is located between the building and the north walkway, and a cesspool is located just northeast of the building.

Building T407, a former latrine and shower, is also located in the center of the site, east of Building T406. A 1,000-gallon UST was formerly situated at the northeastern corner of the building but has since been removed. The building's septic lines are connected to a leach field that is also connected to Building T406. The leach field is located in the clearing east of Building T406 and south of Building T407, and drains into a small wetland on site. The concrete foundation of former Building T466 can still be seen between Buildings T406 and T407.

The former location of a burn pan used for fire training and the temporary drum and debris staging areas (for removals from investigatory sites at the Annex) are located in the parking area at the northern end of the site, just south of the White Pond Road and Puffer Road intersection.

Building T408, formerly used for surveillance of ordnance research and as a barracks, is located on the eastern edge of the site, south of Building T409. Two 1,000-gallon USTs were removed from the area: one from the clearing between Buildings T408 and T409, and the other from the northwest corner of Building T408. On the north side of Building T408 is a camper and monitoring well MW-1. A septic line and cesspool connected to Building T408 extends east from the building. On the eastern side of the building is the site fenceline and beyond the fence is a small southward flowing drainage. Monitoring well E3-P13-M02 is on the southern side of Building T408, and the western side is bordered by the access road that runs between Buildings T407 and T408.

Building T409, formerly used for assembly and packing of material and as a barracks and recreation hall is also located on the northeastern side of the site. Two drums were removed from the area on the northeastern side of this building, between the building and the fence. Monitoring well E3-P13-M03 is located southeast of Building T409. A small drainage flowing southwards borders the eastern side of the area around Building T409.

Buildings T410 (formerly a gas station) and T462 (formerly used for storage and as a fire station) are located on the southern end of the site. Building T410 is a wooden shed bordered on the southern side by the site fence. Monitoring wells MW-1 (ATEC-1) and MW-2 (ATEC-2) are situated on the western side of Building T410 where a 2,000-gallon UST was formerly located. Well MW-3 is located on the northern side of the building, but south of the

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access road that runs between Building T410 and Building T462. Building T462 and monitoring well E3-P13-M04 are located north and south, respectively, of the intersection of two of the site's access roads. A small AST is still connected to Building T462, and a cesspool for Building T462 is located west of the building.

Several buildings have been removed from the site leaving only foundations. Buildings T401, T402, and T403 which were apparently used as offices and as the post exchange were formerly located on the northern side of the site adjacent to White Pond Road in the area immediately northeast of Building T404. Building T419, a former latrine, shower and first aid building was located in the area between Buildings T407 and T409 and was connected to a cesspool. Building T461, possibly a former print shop and storage building was located just east of Building T409. Building T466, a former storehouse, and barracks was located between Buildings T406 and T407. Most of these buildings were demolished in the 1960s. With the exception of Building T466, these foundations have been obscured and are now overgrown with grass. Building T466 foundation is shown on the Plate at the end of this volume.

An overgrown road extends southward from site, over a small tributary to Honey Brook, leading to the Taylor Drop Zone (Site P26). Surface drainage from the western side of the site is via a small wetlands area west of Building T405 into the small tributary to Honey Brook, which is located south of the site. Surface drainage from the central part of the site (between T406, T462 and T408) is via a small on-site wetland into a small drainage that leads to the tributary to Honey Brook. Drainage from the eastern part of the site is into a small drainage way that joins the drainage from the central portion of the site.

#### 1.2 SITE HISTORY

The site history discussion has been culled principally from the Master Environmental Plan (E & E 1994a) and the SI report (E & E 1994b), which, in turn, were derived from reports, memoranda, maps, handwritten notes, and other written materials in the Army's files. These files have been made available to interested parties upon request.

The site area along White Pond Road has been used extensively by varying units and for field test activities, starting in 1952 and continuing until as late as 1991. Probable and confirmed uses of the site include: farming (pre-1942), ordnance research and development (1952 to 1957); laboratory research on foamed plastics, organic chemicals, flame testing, meteorological projects, and insecticide and rodenticide research (1958 to 1982); and training of Massachusetts State Police, Massachusetts Air National Guard, Massachusetts Army National Guard, and MFFA units (1971 to 1991). The site area was the location of a farm prior to Army use, and some of the buildings (T401, T402, T403, T404, T410 and T419) later used by the Army were converted from farm use. The current buildings at the site include Buildings T404, T405, T406, T407, T408, T409, T410, and T462. Former buildings at the site included Buildings T401, T402, T403, T419, T461, and T466. It is important to note, however, that building designations for Buildings T401 and T402 changed between different historical periods at the Annex. Buildings T401 and T402 were noted as within the

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site area in a 1955 map, but by 1964, these designations applied to buildings near the present Sites A8 and A9.

Many of the larger buildings at the site (T405, T406, T407, T408, T409) were built in 1952. During the Maynard Ordnance Testing Station (MOTS) period from 1952 to 1957, the site was the center of ordnance research and development. The exact nature of this research activity has not been identified due to a lack of records and the classified nature of the research. A 1955 map identifies the site as a "Restricted Area," with the following buildings: T401-T409, T419, T461, and T462 present. Building T405 was identified as the "barricade building." Building T406 was used for a "power plant" and machine shop. Building T407 was for miscellaneous use (probably a lavatory). Building T408 was identified as the "surveil" building (presumably surveillance of some kind). Building T409 was identified as the "asses & pack" building (presumably assembly and packaging of material). Building T462 was only identified as "Building D." A 1958 reference to the "Exclusion Area" (meaning the site) noted a plot plan from Arthur D. Little, Inc., one of the contractors identified as using the site for research and development activities for the Army Chief of Ordnance. The 1978 Natick Analysis of Existing Facilities/Environmental Assessment Report stated that the "troop area of about 48 acres, partially enclosed by a security fence . . . was formerly the location of classified ordnance research and development activities."

In 1958, the buildings at the site were converted for use by the Quartermaster Research and Engineering Center (Natick) and its various divisions. A July 1959 memo from the Quartermaster Research and Engineering Center noted the following building use: Building T403 for storage and as a base post exchange (PX); Building T405 as a laboratory; Building T406 as a kitchen and mess hall, Building T407 as a latrine and shower, Building T408 as a barracks, Building T409 as a barracks and recreation hall, Building T419 as a latrine and shower, Building T461 as unassigned with designation "print shop," and Building T462 as a supply building. In 1960, Building T466 was built as a general storehouse. Some of these buildings continued to be used for these same purposes up to site closure. By 1962, Building T410, one of the old farm buildings, had become part of a gas station with gas pumps located in front of it. Building T462 was converted into a fire station, Building T461 was used for storage, while Building T466 was apparently converted into a barracks. By 1964, Building T419 had been designated as a first aid building. Prior to 1966, Building T466 was used for research and development by the Air Drop Engineering Division at Natick. Building T419 was demolished in 1966. Buildings T401, T402, T403 were also apparently demolished sometime in the 1960s, but the exact date could not be determined.

From 1957 until 1982, Building T405 was the center of much of the laboratory research conducted at the Annex during the Natick period. Research was conducted by the following divisions of Natick Laboratories: the Pioneering Research Division (PRD), the Aero-Mechanical Engineering Laboratory (AMEL), the Clothing Equipment and Material Engineering Laboratory (CEMEL), and possibly the Food Division. Research was also conducted by Harvard University (under contract) for the PRD in 1959, and possibly during other years. Other Natick divisions may also have used the building. Research conducted in the building can be divided into four broad areas: fiberglass and polyurethane foam structures; basic chemical research into organic compound reactions under high pressure and

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temperature; impact testing using a shock tube; and insecticide, rodenticide, and defoliant research.

An interview with a Natick employee (Interview 1990) noted that work on fiberglass and polyurethane foam structures was being conducted in 1962. Workers would spray fiberglass and polymer to form foam structures, some of which are still present west of Building T405. The employee said that toluene, benzene, methanol, methyl ethyl ketone (MEK), acetone, peroxide, and other chemicals stored in bunkers at the Annex were used. During a visit in 1962, the AEHA identified the use of twonones–2,4–diisocyanate, amine hardeners, MEK, and peroxide in Building T405. Decontamination water from cleaning spray equipment went into 5-gallon cans and 55-gallon drums. Spray heads were cleaned by spraying them out into the air.

The rooms in Building T405 are also reportedly "explosion proof" and may have been used for chemical mixing. The Natick Environmental Assessment (NARADCOM 1978) noted that the CEMEL used Building T405 to mix chemicals. High pressure and high temperature equipment was recorded as being installed in the building and used for studying organic synthetic reactions at high pressure. The presence of large ovens, sometime between 1964 and 1979, were also noted by another Natick employee (Interview 1992). Flame testing also was recorded as being conducted in the building. The AMEL used a major portion of the building for a large shock tube to test the effect of stress on systems. Building T405 was also the location of some defoliant, rodenticide, and insecticide research in the early to mid-1960s.

A Natick Laboratory employee indicated that chemical dumping and burial may have occurred in and along the southern side of the fence to the west of Building T405 (Interview 1990). The probable source of the chemicals disposed of at the site is from research conducted within Building T405.

Starting in 1969, the Troop Area began to be used to house outside training units. The Massachusetts State Police obtained a lease to use Buildings T406, T407, T408, and T409 for police training purposes starting in May 1969. The MFFA may have used the site in 1971. The Massachusetts Army National Guard was permitted a one-year lease to use Buildings T406, T407, T408, and T409 for training purposes in 1971. After 1971, the Massachusetts Army National Guard was also permitted to use Building T405. According to real property records, the Massachusetts Air National Guard had a permit to use Buildings T406, T407, T408, and T409 and the surrounding 304 acres from January 1973 to January 1978 for training exercises and storage of tactical weather station equipment. The Massachusetts Army National Guard used these same buildings for storage in 1978, in addition to utilizing the gas pump at Building T410. The United States Air Force (USAF) obtained a permit to use Buildings T406, T407, T408, and T409 and the surrounding 304 acres for use by the Massachusetts Air National Guard in 1978, and training continued at least until 1980. Building T404 was leased to the USAF for use as office space for scientists working on meteorological research projects. Building T462 may have also been used by the USAF as an equipment machine shop.

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The CEMEL of Natick Laboratories used Building T406 for fully instrumented mannequin studies in 1975, and was using Buildings T401, T402, T405, T410, and T462 in 1977.

The MFFA used parts of the site at various times beginning in 1971. According to 1971 property records, MFFA used the parking area in front of Buildings T406 and T407 to conduct emergency vehicle driver training and waterholes No. 35 and No. 36 for pumping operations. According to an interview with MFFA personnel (Interview 1991e), MFFA also used the site on a limited basis since 1982. The MFFA used Building T406 for a classroom and Buildings T461 and T462 for storage of equipment. Building use apparently continued through 1988, when the last recorded lease allowing MFFA use of Buildings T406 and T409 expired. Use of the parking area in front of Buildings T406 and T407, where car fire and flammable liquid fire training was conducted, continued at least into the fall of 1991. Car fire training was conducted with the gasoline tanks removed and straw as the combustible material. Flammable liquid fire training was conducted in a pan apparatus using fire extinguishers. A 500-gallon fuel storage trailer was used in connection with the pan fires. According to the MFFA, flammable liquid training was conducted approximately 12 times a year and car training five times a year. Site P13 was not used for chemical fire training or storage. Building T461 was demolished after 1988.

Poor housekeeping of hazardous material by the MFFA was noted in a 1986 Fort Devens memo (Fort Devens 1986). The memo noted that the 500-gallon fuel storage trailer and drip pans were surrounded by dead grass. The burn pan was filled with fuel mixed with water. Numerous stains were observed around the burn pan and dead grass was observed downgradient from the burn pan. By 1991, the burn pan had a plywood cover to keep out rainwater, and a second pan was located below the burn pan to contain spills.

Real Property records indicate that six USTs were located at the buildings in the site. Buildings T405, T407, T408, and T409 all had 1,000-gallon, single-wall, steel USTs for No. 2 Fuel Oil. Building T406 had a 5,000-gallon steel UST for No. 2 Fuel Oil. Building T410 had a 2,000-gallon steel UST for gasoline and several above-ground fuel tanks as well. A heating oil tank is also located in the basement of Building T404. ASTs were located at or near Buildings T406, T410, and T462. Blueprint drawings of the sewer system indicate that Buildings T404, T405, T406, T408, T419, and T462 had cesspools, and a leach field is connected to Buildings T406 and T407.

The key contaminant concerns related to historical activity at the site are discussed in Section 4.1.

#### 1.3 PRIOR REMOVAL ACTIONS

Removal actions by ATEC and OHM are described below.

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#### 1.3.1 Removal Actions by ATEC, Inc. in 1992

Six USTs were removed by ATEC in 1992 and are described in the following paragraphs according to their location. The purpose of the tank closures was to excavate the USTs, evaluate the potential for the presence of oil and hazardous material at the site, and remove any petroleum-contaminated soil.

### 1,000-Gallon UST at Building T405

In October 1992, a 1,000-gallon, No. 2 Fuel Oil, single-steel-walled UST was excavated approximately 5 feet east of the north end of Building T405. Upon excavation and removal, the tank was observed to be in good condition without holes, perforations or severe corrosion. ATEC obtained soil samples from the excavation for field screening and photoionization detector (PID) and Non-Dispersive Infrared (NDIR) analysis. The PID results indicated no detectable total organic volatiles (TOV) concentrations, while NDIR analysis revealed total petroleum hydrocarbon (TPHC) concentrations from 7.5 ppm to 63.1 ppm. Two samples were also collected for laboratory analysis. Soil sample LSS-1, collected from the north wall of the excavation, did not detect any TPHCs above the Method Reporting Limit (MRL). However, soil sample LSS-2, collected from the bottom of the excavation, detected TPHC at a concentration of 23.0  $\mu$ g/g. Analysis sample P13CU2, collected by OHM during the excavation of the UST, indicated TPHC at 13  $\mu$ g/g in soils at the bottom of the excavated to free the tank (ATEC 1993).

# 5,000-Gallon UST at Building T406

A 5,000-gallon, No. 2 Fuel Oil UST, located approximately 4 feet west of Building T406, was excavated and removed from the site in October 1992. During the removal, the tank was observed to be in good condition without holes, perforations, or severe corrosion. Soil removed during the excavation was not visibly contaminated. Analysis of the tank contents indicated the following semi-volatile organics: acenaphthylene; acenphthene; anthracene; di-n-butylphthalate; fluoranthene; 2-methylnaphthalene; and naphthalene. Prior to tank removal, approximately 200 gallons of No. 2 Fuel Oil were removed from the UST by Hitchcock Gas Engine Company. Laboratory analysis of soil samples taken from the excavation did not detect any TPHCs above the MRL (ATEC 1993). No TPHC was detected in an additional sample, P13CU1, collected by OHM from the excavation (OHM 1994). However, a trace amount of toluene (0.0023  $\mu$ g/g) was found to be present. The excavation backfill consisted of the same soil that had been removed to free the tank (ATEC 1993).

# 1,000-Gallon UST at Building T407

A 1,000-gallon, No. 2 Fuel Oil UST, located at the northwest corner of Building T407, was excavated and removed from the site in May 1992. During the excavation, the soil showed evidence of petroleum contamination, such as staining and discoloration. The tank appeared to be in good condition with the piping intact, although slightly corroded. Prior to tank removal, Lincoln Environmental, Inc. removed approximately 65 gallons of

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No. 2 Fuel Oil and water from the UST. PID field screening of soil samples obtained from the excavation revealed TOV concentrations up to 9.4 ppm. NDIR results revealed only one sample (at 287.2 ppm) with a TPHC concentration above the Massachusetts Department of Environmental Protection (MDEP) remedial goal of 100 ppm in effect at the time. Since this removal action the remedial goal has been raised to 500 ppm. Laboratory analysis of two soil samples indicated TPHC concentrations at  $16 \mu g/g$  in the excavation wall and  $19 \mu g/g$  in the bottom of the excavation. The excavation was backfilled with native soil obtained during tank removal (ATEC 1993).

#### 1,000-Gallon UST at Building T408

A 1,000-gallon, No. 2 Fuel Oil, single-steel-walled UST was removed from the northwest end of Building T408 in May 1992. Soil removed during the excavation appeared stained, especially along the bottom of the excavation. The bottom of the excavation was 7 feet, 6 inches below ground surface (BGS), and groundwater was encountered at 4 feet, 6 inches BGS. Both the tank and its associated piping appeared to be in good condition, although the piping was slightly corroded. For hazardous waste characterization purposes, a sample of the No. 2 Fuel Oil was analyzed and found to contain the following semi-volatile organics: acenaphthylene, isophorone, 2,6-dinitrotoluene and 2-methylnaphthalene. In addition, laboratory analysis revealed volatile organics including toluene, ethylbenzene, total xylenes, tetrachloroethane, and benzene. Prior to tank removal, approximately 783 gallons of No. 2 Fuel Oil and water were removed from the UST by Lincoln Environmental, Inc. Laboratory analysis of two soil samples obtained from the excavation revealed TPHC at concentrations of 23  $\mu$ g/g and 56  $\mu$ g/g. Analysis of a groundwater sample detected TPHC at 32,000  $\mu$ g/L (ATEC 1993).

Remediation activities at this location included the excavation of an additional 28 tons of soil to reach background levels of less than 1 ppm according to PID analysis. However, excavation activities ceased when groundwater was encountered at 4 feet, 6 inches BGS. Laboratory analysis of soil samples from the side walls of the post-remedial excavation revealed TPHC concentrations ranging from 20  $\mu$ g/g to 27  $\mu$ g/g and no detectable concentrations of volatile organic compounds (VOCs) above their respective MRLs. By October 1992, approximately 28 tons of contaminated soil were disposed of by Trimount Bituminous Products. The excavation was backfilled with sand (ATEC 1993).

As a result of the TPHC concentrations in the soil and groundwater samples obtained from the original excavation, groundwater monitoring well MW-1 was installed approximately 37 feet northwest of Building T408 in October 1992. MW-1 was installed to a depth of 12 feet BGS to assess soil and groundwater contamination that may have resulted from the potential release of No. 2 Fuel Oil from the UST. No petroleum odors were noted and no TOV concentrations were detected in PID field screening of soil samples from the monitoring well boring. NDIR screening indicated TPHC concentrations ranging from 3.4 to 10.4 ppm. No detectable concentrations of TPHC were found in the groundwater sample collected from MW-1 (ATEC 1993).

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#### 1,000-Gallon UST at Building T409

A 1,000-gallon, No. 2 Fuel Oil, single-steel-walled UST was removed near the south end of Building T409 in May 1992. The soil removed during the excavation revealed evidence of petroleum contamination such as staining and discoloration. The bottom of the excavation was approximately 8 feet BGS, the same depth at which groundwater was encountered. Associated piping proved to be intact, although slightly corroded, and the tank appeared to be in good condition with no pin holes or perforations. Prior to tank removal, approximately 670 gallons of No. 2 Fuel Oil and water were removed from the UST by Lincoln Environmental, Inc., and disposed of by Cyn Environmental Services. Analysis of groundwater encountered during the excavation revealed no detectable TPHC concentrations above the MRL. PID readings from soil samples obtained from the excavation for field screening revealed TOV concentrations ranging from 0.1 ppm to 25.0 ppm; NDIR results from the same samples revealed TPHC concentrations ranging from 3.2 ppm to 94.9 ppm. Analytical results of confirmation samples from the excavation showed TPHC ranging from  $11 \mu g/g$  to  $15 \mu g/g$  (ATEC 1993).

Remediation activities at the site included removing an additional 30 tons of soil to reach background levels of less than 1 ppm using a PID to field screen soil samples. PID screening of post-remedial soil samples, collected from approximately 3 to 4 feet BGS, revealed TOV levels ranging from 0 ppm to 0.4 ppm. TPHC concentrations ranged from 11  $\mu$ g/g to 63  $\mu$ g/g in laboratory analysis of post-remedial soil samples. The excavation was backfilled with sand (ATEC 1993).

### 2,000-Gallon UST at Building T410

A 2,000-gallon UST was excavated from west of Building T410 in May 1992. The tank was observed to be corroded, and the excavated soil revealed evidence of petroleum contamination such as staining and discoloration. The piping was intact, although slightly corroded. Groundwater was not encountered during the excavation. Prior to tank removal, approximately 27 gallons of gasoline and water were removed from the UST by Hitchcock Gas Engine Company of Bridgeport, Connecticut. PID readings of soil samples for field screening revealed TOV concentrations reaching 8.5 ppm. NDIR analysis revealed TPHC concentrations ranging from 8.9 ppm to 182.4 ppm. Laboratory analysis of two soil samples indicated TPHC concentrations up to 12  $\mu$ g/g. In October 1992, Bardon Trimount Bituminous Products of Shrewsbury, Massachusetts removed and disposed of 140.4 gallons of gasoline contaminated soil. Analysis of post-remedial soil samples from the excavation indicated TPHC concentrations ranging from 11 µg/g to 187 µg/g. Three groundwater monitoring wells were installed: MW-1, MW-2, and MW-3. NDIR analysis of soil samples from the monitoring well borings detected TPHCs in a range of 15.9 ppm to 322 ppm. No TPHC or VOCs were found above the MRL in groundwater samples from the three wells. The excavation was backfilled with sand (ATEC 1993).

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#### 1.3.2 Removal Actions by OHM in 1991

OHM removed several empty drums from the site and relocated them to the temporary drum storage area, the former MFFA training area, located at the north end of the site. Surface soil samples were collected to assess the potential contamination that may have resulted from leaking drums. Empty drums were located west of Building T405, between Buildings T406 and T462, east of Building T409, and near monitoring well EHA3. There was no visible staining and no readings above background levels in the soils beneath any of the drums (OHM 1994). Analysis results of drum confirmation samples are discussed in Section 4.2.1.

In 1992, several ASTs were removed by Fort Devens personnel from near Buildings T406 and T410. Eight samples were collected by OHM (P13CA1 through P13CA8) at the former AST locations at Buildings T406 and T410 and at the existing UST at Building T462 for laboratory analysis. Analysis results of these samples are discussed in Section 4.2.1.

#### 1.4 PREVIOUS INVESTIGATIONS

Earlier investigations at Site P11/P13 conducted by AEHA and OHM are described below.

#### 1.4.1 Hydrogeological Investigation and Subsurface Evaluation by AEHA in 1983

The AEHA conducted a hydrogeological investigation and subsurface evaluation at the Annex between 16 and 18 May 1983. The Corps of Engineers installed monitoring well EHA3 in April 1983 west of the site across White Pond Road from Building T404. This well was one of six at the Annex located hydraulically downgradient of disposal sites that appeared to have the greatest potential for groundwater contamination. However, the AEHA report did not identify which site(s) the installation of EHA3 was meant to help assess. The goal of this sampling was to characterize the suitability of the groundwater as a drinking water supply according to the National Interim Primary Drinking Water Regulation (NIPDWR) Standards (USAEHA 1983).

Sampling procedures involved purging the wells then using a suction pump and a stainless steel bailer to sample them. Characteristics of well EHA3 include the following: a 14.8 foot depth to water from the top of the casing; a length of 1.8 feet of casing above ground surface; a 13.0 foot depth to water from ground surface; inside diameter of the casing of 2 inches. Five gallons of water were pumped prior to sampling and two gallons of water were collected for the sample. Sample analysis consisted of gas chromatography for purgeable, base/neutral, and acid extractable organic priority pollutants. Results from the first sample in this well indicated that nitrogen, in the form of nitrate and nitrite, was present at 3.00  $\mu$ g/L, where the detection limit was 0.05  $\mu$ g/L. A second sample did not show any parameters above the detection limit. AEHA concluded that the data presented no evidence of significant groundwater contamination (USAEHA 1983).

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## 1.4.2 Previous Investigation by OHM in 1991

In 1991, OHM conducted a SI that consisted of a soil gas survey, a geophysical study, test pit excavations with subsurface soil sampling, monitoring well installation with subsurface soil sampling, groundwater sampling, a hydrogeologic assessment, removal of empty 55-gallon drums, and confirmatory sampling at each drum location. The purpose of their investigation was to identify potential contamination that may have been introduced by previous activities at the site. Activities of concern include the alleged chemical dumping along the fence west of Building T405, fire fighting training by the MFFA, and activities involving USTs and ASTs in the area (OHM 1994).

Target Environmental Services performed the soil gas survey under the supervision of OHM in August 1991. The purpose of the survey was to detect volatile compounds in the soils and help OHM locate test pits and soil sample locations. Samples were collected in three areas. Samples collected just west of Building T405 displayed no chlorinated hydrocarbons or benzene, toluene, ethylbenzene, and xylene (BTEX) constituents. However, Total Flame Ionization Detector (FID) volatiles were detected outside the wetland portion of the area and on the northern portion of the site. Ethylbenzene (2.2  $\mu$ g/L), xylenes (3.2  $\mu$ g/L), and total FID volatiles (273  $\mu$ g/L) were detected on the eastern portion of the site just west of the road between Buildings T407 and T408 (OHM 1994).

In July and August 1991, electromagnetic conductivity (EM), magnetic radiometry (magnetics), ground penetrating radar (GPR), and scanner magnetometry (SM) studies were conducted by Neponset Geophysical Corporation under the direct supervision of OHM. The purpose of these studies was to identify potential contamination, locate burial and disposal areas, and locate the six USTs. In addition, OHM used the results to place borings, monitoring wells, and test pits, and to determine which areas would require further investigation (OHM 1994).

EM, magnetics, and SM studies were conducted outside the fence located west of Building T405. Several EM and magnetics anomalies were detected, but are assumed to be the result of nearby buildings, the chain-link fence, or scrap metal on the surface. The six USTs were located and marked on the site using SM and GPR studies. UST locations and sizes were as follows: a 5,000 gallon UST at the northwest corner of Building 406; a 2,000 gallon UST east of Building T410; and four 1,000 gallon USTs located respectively at the northeast corner of Building 405, at the northeast corner of Building 407, at the northwest corner of Building 408, and at the southwest corner of Building 409. ATEC excavated overburden soil and removed the USTs under the contract and supervision of Fort Devens (OHM 1994).

In December 1991, two test pits were excavated in locations based on the highest soil gas results in the area. The test pits were used to determine possible sources of contamination identified by geophysical surveys and visual observations. Test pit P11TPA, located outside of the fence west of Building T405, was excavated to a depth of only 4 feet BGS because groundwater was encountered. Soil samples, collected at 2 and 4 feet BGS indicated no photoionization detector (PID) or radiological survey meter readings above background. Test

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pit P11TPB was excavated just south of White Pond Road and north of test pit P11TPA. P11TPB was completed to a depth of 6 feet BGS with soil samples collected at 2, 4, and 6 feet BGS. No readings were detected above background on the PID or radiological survey meter. Laboratory analytical results of test pit sampling are discussed in Section 4.2.4 of this report (OHM 1994).

As part of the SI, OHM collected surface soil samples in the approximate location of the burn pan used by the MFFA and below removed and existing ASTs. Subsurface soil samples were collected during removal of USTs at Buildings T405 and T406. Analytical results of these soil samples are discussed in Sections 4.2.1 and 4.2.3 of this report.

In February 1992, OHM evaluated monitoring well EHA3 to determine if any deterioration had been caused by chemical erosion, mechanical erosion, or vandalism. No deterioration was noted at EHA3. In March 1992, OHM installed three monitoring wells around Building T405 to detect any contamination that may be related to the building. Well OHM-P11-32 was installed on the western side of Building T405 to a depth of 15 feet BGS. However, this well was abandoned upon finding that the well was screened below the water table, and was relocated approximately 5 feet north of the abandoned borehole. Well OHM-P11-33 was installed near the southeast corner of Building T405 to a depth of 15 feet BGS. Well OHM-P11-34 was installed northwest of Building T405 to a depth of 18 feet BGS. No PID or radiological readings above background were detected in any of the three wells (OHM 1994).

In June and November 1992, groundwater samples were collected from EHA3 well and the three OHM wells to characterize the quality of the groundwater in the area. Sampling analytical results are discussed along with the E & E groundwater sampling results in Section 4.2.5.

All of the OHM analytical data for field sampling at the site are available in the OHM Final Site, Remedial Investigation Report for the Sudbury Annex (January 1994).

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# 2. E & E FIELD ACTIVITIES AT SITE P11/P13

In 1993 and 1994, E & E conducted an environmental investigation of the site, which included the following field activities: a seismic survey; EM and magnetometer surveys; monitoring well installation and development; topographic surveying; ecological field surveying; exploratory pit excavation; groundwater sampling; and surface water and sediment sampling.

# 2.1 ANALYTICAL PARAMETERS AND SAMPLING EFFORTS

All samples collected during the field investigation, with the exception of geotechnical samples, were analyzed for Target Compound List (TCL) Organics, Target Analyte List (TAL) Metals, TPHCs, and herbicides. Table 2-1 summarizes the samples by type and includes sample dates, analyses performed, and sampling rationale for samples collected at the site. Sample locations are included on the Plate at the end of this volume, with the exception of two surface water/sediment sample locations which are downgradient of the site and are shown on the Plate at the end of Volume I.

	7	Table 2-1		
	PHASE II SA	AMPLING EI	FFORT	
Sample Type	Samples (Site IDs)	Sample Date(s)	Analysis	Sampling Rationale
Groundwater	19 (OHM-P11-32/33; EHA3; ATEC-1; ATEC-2; E3-P11- M01; E3-P13- M01/M02/M03/M04)	08/24/93 08/25/93 09/02/93 11/29/93 11/30/93	TAL Metals TCL Organics TPHC Herbicides	Samples were collected to characterize groundwater quality and the potential for contaminant migration through the groundwater pathway.
	5 (E3-P11-M01; E3-P13-M01/M02/M03/M04)	08/02/03 08/03/93	тос	Samples collected from the saturated zone for TOC analysis to characterize the nature of subsurface soils and the groundwater pathway.
Subsurface Soils	5 (E3-P11-M01; E3-P13-M01/M02/M03/M04)	08/02/93 08/03/93	Grain size Atterberg limits	Geotechnical samples were collected to help assess the nature of subsurface soils and their impact upon groundwater hydraulic conductivity.

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	,	Table 2-1		
	PHASE II S	AMPLING E	FFORT	
Sample Type	Samples (Site IDs)	Sample Date(s)	Analysis	Sampling Rationale
Surface Water	8 (E3-P11-D01/D02/D03/D04; E3-P13-D01; E3-P13-D03/D04/D05)	08/02/93 08/03/93 09/15/93 12/01/93 12/02/93	TAL Metals TCL Organics TPHC Herbicides	The surface water and sediment samples were collected to investigate the impact of past site activities on the streams in the area and the potential for the streams and wetland areas to act as future contaminant sources.
	1 (E3-P11-D04)	04/26/94	TAL Metals TPHC TSS	This sample was recollected due to a high sediment content in the earlier sample collected on 12/02/93.
	9 (E3-P11-D01/D02/D03/D04; E3-P13-D01/D02/D03/D04/ D05)	08/02/93 08/03/93 09/01/93 09/15/93 12/01/93 12/02/93	TAL Metals TCL Organics TPHC Herbicides	See surface water sampling rationale.
Sediment	1 (E3-P11-D04)	04/26/94	TAL Metals TPHC TOC	The sample was collected to confirm earlier sampling results.
	9 (E3-P11-D01/D02/D03/D04; E3-P13-D01/D02/D03/D04/ D05)	08/02/93 08/03/93 09/15/93 12/01/93	TOC -	Samples collected for TOC analysis to characterize sorption potential of sediments.
	9 (E3-P11-D01/D02/D03/D04; E3-P13-D01/D02/D03/D04/ D05)	08/02/93 08/03/93 09/15/93 12/01/93	Grain size, Atterberg limits	Geotechnical samples were collected to characterize the nature of sediment.

Source: Ecology and Environment, Inc. 1994.

Subsurface soil samples were collected from the five E & E installed monitoring wells for TOC analysis to characterize the nature of subsurface soils and their impact on the groundwater pathway. Geotechnical samples were also collected from the five wells for grain size and Atterberg limits analyses to characterize the nature of subsurface soils and their impact on groundwater hydraulic conductivity. Sediment samples were also collected for TOC, grain size, and Atterberg limits analyses to characterize the nature of sediments in these streams.

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#### 2.2 GEOPHYSICAL SURVEYS

Geophysical investigations were conducted in the cleared areas between Buildings T406, T407, and T462 to identify the location of the leach field attached to Buildings T406 and T407. The investigations included EM and magnetometer surveys. The EM survey consists of using the EM31 meter which continuously measures the apparent terrain conductivity of materials beneath and immediately surrounding the area. Magnetometry surveys help to identify and map the presence of ferromagnetic objects.

Background research was conducted prior to the geophysical investigations, and blueprint designs for the buildings' planned sewer system were obtained to assist the geophysicists during the surveys. The surveys identified several locations that would be further investigated by exploratory test pits excavated with a backhoe. The approximate layout of the septic system and leach field was identified in the area in front of Buildings T406, T407, and T462. No unusual anomalies were noted.

Although no geophysical studies were conducted on the west end of the site, a thorough reconnaissance survey of the area immediately surrounding Buildings T404 and T405 identified two cesspools and vent pipes which were probably used for each building.

# 2.3 MONITORING WELL INSTALLATION AND DEVELOPMENT

In order to characterize the groundwater quality at the site, E & E installed, developed, and sampled five shallow overburden monitoring wells at various locations along the fenceline of the site. Well locations were chosen based upon the results of a seismic survey, which was conducted at the site to identify the underlying bedrock or till contours which were expected to control groundwater flow. The seismic survey results and the geology of the area are more completely described in the geology description in Section 3. All five wells were sampled in August and November 1993, with both filtered and unfiltered samples collected during each round.

Well E3-P11-M01 is located in the clearing south of Building T405, in the southwestern corner of the site. The well is screened across the water table at an interval of 6 to 16 feet BGS. Groundwater was encountered at 8 feet BGS. This well is located to monitor contamination that might come from Building T405, the removed 1,000 gallon UST located at the northwest corner of Building T405, or from the central area of the site.

Well E3-P13-M01 is located in the northwest part of the site, between Building T404 and the approximate location of the burn pan, and about 50 feet south of the entrance road to the buildings. The well is screened across the water table at an interval 9 to 19 feet BGS. Groundwater was encountered 14 feet BGS. This well is placed to monitor any groundwater contamination that could migrate from the northern portion of the site.

Well E3-P13-M02 is located at the eastern edge of the site, approximately 40 feet southeast of Building T408. The well was completed adjacent to the wetlands which border the eastern edge of the site, and was screened below the water table at an interval of 8 to 18

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feet BGS. Groundwater was encountered 4 feet BGS. Since this well is located downgradient of Building T408 any contamination from this building would likely be detected in this well.

Well E3-P13-M03 is located along the northeastern edge of the site, upgradient of Buildings T408 and T409. The well is screened below the water table at an interval 8 to 18 feet BGS. Groundwater was encountered 5.5 feet BGS. This well is located upgradient of all known sources at the site, and was installed to characterize local groundwater background conditions.

Well E3-P13-M04 is located at the southern edge of the site, approximately 100 feet southwest of Building T462, and lies at the intersection of one of the site roads and the overgrown access road which connects the site to Site P26 (Taylor Drop Zone). This well is screened across the water table at an interval 8.6 to 18.6 feet BGS. Groundwater was encountered 9 feet BGS. The well was completed downgradient of the central part of the site, part of Building T406, and all of Buildings T410 and T462, and, therefore, monitors contamination that may be associated with these areas.

In addition to these newly installed wells, E & E also sampled five existing monitoring wells to further assess groundwater quality and the potential for contaminant migration. Four of the five wells (OHM-P11-32, OHM-P11-33, ATEC-1, and ATEC-2) were sampled during two groundwater sampling events, the first in August 1993 and the second in December 1993. The fifth well, EHA3, was sampled only on one occasion during the second round in December 1993. Filtered and unfiltered samples were collected at each well during both sampling rounds. Wells ATEC-1, ATEC-2, and EHA3 were added to the original site sampling plan after field observations identified existing wells in locations downgradient of potential sources. The additional samples were added to further characterize groundwater quality and investigate the presence of any contaminant plumes in the groundwater pathway.

#### 2.4 TOPOGRAPHIC SURVEYS

Topographic surveys were conducted at the Annex to determine surface water drainage pathways, and to provide a base map of the sites. Surveys were performed by E & E's subcontractor, Golden Land Survey of Plymouth, Massachusetts. Each item was located to an accuracy of  $\pm 3.0$  feet on the Massachusetts State Plane Coordinate System (NAD27). All elevations were determined to an accuracy of  $\pm 0.05$  feet, referenced to the National Geodetic Vertical Datum of 1929 (USATHAMA 1987). Results of the topographic survey completed at the site are shown on the Plate at the end of this report.

#### 2.5 WATER LEVEL MEASUREMENTS

Water level measurements were used at the site to calculate groundwater elevations and hydraulic gradients, and to determine general and site-specific groundwater flow at the Annex. Measurements were made of all site monitoring wells and surface water staff gauges on 13 September and 3 December 1993. Water elevations were higher on 3 December and reached a maximum of 198.09 feet above mean sea level (AMSL) at monitoring well E3-P13-M03, which was used as the local background well for the site. The minimum water

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elevation at the site was recorded on 13 September with a reading of 192.90 feet AMSL at well OHM-P11-34. The depth to water ranged from 0.03 feet BGS at well E3-P13-M02 to 13.09 feet BGS at well E3-P13-M01. These depths were both recorded on 3 December 1993. Surface water elevations were also measured on 27 April 1994. The full results of these measurements are presented in Appendix C and were used to develop the understanding of groundwater contour and flow and surface water flow directions and are discussed in detail in Section 3.

#### 2.6 AQUIFER TESTING

Aquifer testing consisted of hydraulic conductivity tests (slug tests) used to determine the rate of groundwater flow, the transport rate of contaminants within the groundwater, and volume of groundwater flow by calculating the hydraulic conductivity at the site. The tested wells at the Annex sites were grouped into four geographical areas. Site P11/P13 were part of the "Northern Area of the Annex", where the average hydraulic conductivity was found to be 0.00934 feet per minute, the highest value of the four geographical areas at the Annex. The average transmissivity for this geographic area was calculated to be 0.08434 square feet per minute, which was the third highest value of the four geographical areas at the Annex. Slug tests were performed at monitoring wells E3-P11-M01, and E3-P13-M01 through E3-P13-M04, between 2 and 3 August 1993. The complete results of slug testing are presented in Appendix G and are discussed in detail in Section 3.

#### 2.7 EXPLORATORY PIT EXCAVATION

A geophysical study, consisting of EM and magnetometer surveys, was conducted to assist in the identification of the septic field associated with Buildings T406 and T407 located in the center of the site. The location of the system was deduced from the geophysical data as well as from a blue print drawing of the site sewer system. Four exploratory pits were excavated in order to trace the septic lines from these two buildings. The results showed that the septic lines from these two buildings meet at a junction box (at E3-P13-EP01) approximately 100 feet northeast of Building T406 and 75 feet directly south of Building T407. Both buildings utilize a septic field which is located below the junction box and is oriented in a southeasterly direction. The field extends approximately 225 feet southeast of the junction box. Drainage from the field enters a small wetland, which drains under a dirt road to the southeast. No odors or visible signs of contamination were observed during the exploratory pit excavation.

#### 2.8 FIELD SAMPLING

Field sampling activities at this site included groundwater sampling, subsurface soil sampling, and surface water and sediment sampling. Information regarding sampling locations are described in the following sections. Sampling procedures have been described in Volume I, Section 2. Results from the sampling are discussed in Section 4.

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# 2.8.1 Groundwater Sampling

Groundwater samples were collected to determine groundwater quality and assess the potential need for future groundwater remedial action. Samples were collected in August or September, and in November 1993 from ten wells located at the site and analyzed for TAL Metals, TCL Organics, TPHC, and herbicides. Prior to sampling, each well was purged of five times the volume of water calculated to be in the well bore and in the saturated annulus of sand pack around the well screen. Groundwater quality was monitored before and during purging to assure consistent readings of temperature, pH, and turbidity by the end of purging. Filtered samples were collected for metals analysis using a filter with a 0.45 micron pore size. All on-site wells were sampled twice, but EHA3 was only sampled in the November 1993 sampling round and included in the same sample analysis.

# 2.8.2 Subsurface Soil Sampling

During monitoring well installation, geotechnical samples were collected from the saturated zone in each of the five wells and sent for grain size and Atterberg limits analyses. In addition, samples were collected from each of the wells near the screened intervals and analyzed for TOC content. These samples provide data to assess the nature of the subsurface soils in the area and their potential effect on contaminant migration in the groundwater pathway.

# 2.8.3 Surface Water and Sediment Sampling

Surface water and sediment samples were collected from nine locations to characterize the water quality and sediments of the eastern, western, and southern drainages from the site and to characterize the water quality and sediments of the water downgradient of the groundwater seep located north of the site across White Pond Road. Surface water and sediment samples were analyzed for TAL Metals, TCL Organics, TPHC, and herbicides. Sediment samples were also collected for TOC, grain size, and Atterberg limits analyses. Surface water/sediment sampling locations are identified on the Plates at the end of Volumes I and II.

Surface water/sediment sample location E3-P11-D01 lies to the west of Building T405 in the wetlands and intermittent streambed which drains south toward the tributary to Honey Brook. Sample location E3-P11-D01 was chosen downgradient of the alleged disposal area along the fence west of Building T405, and lies below a surface drainage pathway which feeds the wetlands area. Any contamination that may have resulted from the UST located at the northwest corner of Building T405, or from past activities at Building T405, might be detected in samples taken at this location.

Sample location E3-P11-D02 was chosen further downstream of E3-P11-D01, and upstream of the bridge over the tributary to Honey Brook that connects this site to Site P26. This surface water/sediment sample location is located south of the site.

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Sample location, E3-P11-D03, is located downstream of both the study site and Site P26. This location was chosen to corroborate chemical data with biological data collected from a Rapid Bioassessment (RBA) sampling point measured in May 1993. The RBA sampling point and E3-P11-D03 surface water and sediment sampling location lie in Honey Brook, approximately 50 feet northeast of the point where Puffer Road crosses Honey Brook.

Sampling location E3-P11-D04 was chosen to characterize surface water and sediment quality downstream of a groundwater seep that receives groundwater flow from the northern portion of the site. The seep flows in a northerly direction on the east bank of a wetland, and is located approximately 600 feet north of the site across White Pond Road.

Sample location E3-P13-D01 lies at the convergence of the intermittent streams that drain the central and eastern area of the site. This convergence lies southeast of the site and continues on to converge with the tributary to Honey Brook that runs south of the site.

Sample location E3-P13-D02 was chosen to characterize any contamination in the wetlands and intermittent streambed which lie along the eastern edge of the site. The location is south of the small pond which lies near the intersection of White Pond Road and Puffer Road. The wetlands lie between Puffer Road and the eastern edges of the site, and act as the main recipient of surface runoff from the northeastern portion of the site.

Surface water and sediment sample location E3-P13-D03 was chosen to characterize water quality in the drainage which carries surface runoff from the on-site wetland and the southeastern corner of the site. The runoff channel originates near the bend in the road between Buildings T462 and T408, approximately 250 feet south of monitoring well E3-P13-M02. This drainage also receives flow from the Building T406/T407 leach field.

Sample locations E3-P13-D04 and E3-P13-D05 are both located in the tributary to Honey Brook, downstream of E3-P13-D01.

Geotechnical samples were collected from the surface water/sediment sampling locations and sent for grain size and Atterberg limits analyses. The samples provide data to characterize the stream sediments, their impact upon the surface water pathway, and the potential for contaminant migration. Sediment samples were also analyzed for TOC.

Due to the relatively dry summer of 1993, surface water samples could only be collected from locations E3-P11-D03 and E3-P13-D01 during the August 1993 sampling event. In order to complete the original work plan sampling requirements, surface water samples were collected from locations E3-P11-D01, E3-P11-D02, and E3-P13-D03 through E3-P13-D05 during the relatively wet period of December 1993. No surface water sample could be collected at location E3-P13-D02 due to a lack of water. Sediment samples were collected from all locations except E3-P11-D04 in September 1993. E & E recollected surface water and sediment samples for herbicide analysis from E3-P11-D02 in September 1993. Sediment samples were recollected at all five P13 sediment locations in December 1993 and analyzed for herbicides. During the December sampling event, surface water and sediment samples were collected from the groundwater seep at location E3-P11-D04. Surface

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water samples were recollected at location E3-P11-D04 in April 1994 due to the presence of a large quantity of sediments in the surface water sample in the December 1993 sampling round. A small pond was excavated with a shovel 24 hours prior to sampling to ensure a sediment-free surface water sample.

#### 2.9 ECOLOGICAL ASSESSMENT

The ecological assessment involved conducting an ecological characterization of the site as well as rapid bioassessment of the Honey Brook system.

#### 2.9.1 Ecological Characterization

An ecological characterization of the P11/P13 site was conducted to provide information for the baseline risk assessment (human health evaluation and ecological evaluation). The primary objective of the characterization was to identify and evaluate existing aquatic, terrestrial, and wetland communities. Other objectives included mapping and describing plant communities within the site, observing wildlife species present in the vicinity of the site, identifying and evaluating significant ecological resources that could be impacted by contamination from the site, and noting evidence of plant or animal stress that may be a result of site contamination. Emphasis was placed on sensitive environments or species that may come in contact with site contamination, such as State- or federally-designated wetlands, critical habitats, and species of concern. Based on E & E's preliminary evaluation of available information on site ecology and a site visit, conducted 22 June 1993, the ecological resources potentially impacted by the site were identified for further characterization. These resources include aquatic and wetland communities in the vicinity of the site, as well as terrestrial vegetation and wildlife species living on or in the vicinity of the site.

The methodology for the ecological surveys including wetland delineation and functional assessment, cover-type mapping, agency contacts, literature review, and wildlife use of the site are provided in Volume I (Section 3.1.8).

# 2.9.2 Rapid Bioassessment (HB-1)

RBA is a method used to determine the biological condition of a stream or river. Samples are collected and compared to an off-site background stream. The stream or river is then evaluated to determine the extent of impairment, if any, that has taken place. The biological condition of the stream can then be ranked as one of the following: non-impaired, moderately impaired, or severely impaired; impaired is defined as a reduction in species comparable to the best situation to be expected within an ecoregion. Stream flow, bottom characterizations, and riparian vegetation descriptions are also assessed in RBA.

RBA station HB-1 (Honey Brook) is located in a partially forested area south of the study site, and downstream from the Puffer Pond Road crossing of Honey Brook. This location was surveyed and sampled by an E & E field team between 24 and 26 May 1993. Samples collected at this station were compared to RBA reference station TB-1 (Taylor Brook) located east of station HB-1, and outside and upgradient of the Annex. Results at

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RBA station HB-1 indicated that the Honey Brook system appears to be non-impaired relative to the reference station TB-1. In addition, the conditions at station HB-1 are what can be expected in the regional area with respect to stream size and quality. Further description of the procedures and results of the RBA can be found in Volume IV, Appendix L.

# 2.10 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

# 2.10.1 Site Data Review Procedures

This section provides a summary of the results of the Quality Assurance/Quality Control (QA/QC) review performed using the protocol described in Volume I, Section 3.2.2.

Data for Watershed 1B, collected by E & E during the SIs and RIs of sites at the Annex, were evaluated for usability by reviewing laboratory and field QC sample data for contamination possibly introduced into field samples by either sampling or analysis procedures. First, method blanks were reviewed for each analyte in the 239 lots associated with Watershed 1B, followed by trip blanks and then rinsate blanks. Following consideration of laboratory and field QC blank samples data, laboratory flagging codes and USAEC data qualifiers were evaluated with laboratory control charts for each lot and sampled for quality assurance problems. Analytical results were then reviewed for precision through consideration of the relevant percent difference (RPD) between each sample/duplicate pair and matrix spike/matrix spike duplicates (MS/MSD) sample set.

Following is a discussion of samples for each area affected by QA/QC evaluation. Samples with contamination also found in the blank were qualified either with a "B" usability code for "present in the blank" or a "K" usability code for a result-biased high. Samples considered to have quality assurance problems were qualified with either an "L" usability code for result-biased low or "R" for rejected. Appendix F provides a list of all QC summary data for method blanks, trip blanks, rinsate blanks, field duplicate samples, and MS/MSD samples. It is important to note, as discussed in Appendix F, that method blank results for TAL metals were not used to qualify soil or sediment sample data because the USAEC Repository Standard Soil had low levels of metals that do not correspond to the native soils surrounding the Annex. Therefore, only rinsate blanks were used to qualify the results for TAL metals in soil samples based on blank contamination.

#### 2.10.2 Data Usability

#### 2.10.2.1 Site P11 -- Building T405 Area

## Samples Collected Prior to April 1994

Blank contamination was found for 16 different analytes in 194 samples. Acetone, aluminum, bis(2-ethylhexyl)phthalate, methylene chloride, endosulfan sulfate, potassium, sodium, lead, and zinc were each detected in at least one method blank. Aluminum, lead, zinc, and sodium were contaminants due to the source water used to prepare the standard matrix. Acetone, methylene chloride, and bis(2-ethylhexyl)phthalate are considered common

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laboratory contaminants. Endosulfan sulfate can be attributed to carryover from laboratory equipment. Aluminum, antimony, cadmium, heptachlor, iron, lindane, manganese, methylene chloride, sodium, TPHC, potassium, and zinc were found in the rinsate blanks and are attributable to either the source water or to particulates from the sampling equipment entrained with the rinsate source water put into the sample containers. The only volatile organic found in the trip blanks was methylene chloride, which was attributed to laboratory contamination.

Analytes for which some samples were biased high were lead, magnesium, manganese, potassium, sodium, and zinc because these analytes were found at concentrations which were greater than five times the concentration found in either the rinsate or method blank, but less than ten times the rinsate or method blank level.

Analytes which were found to exceed RPD precision criteria for duplicate samples included aluminum, arsenic, barium, and iron. As a result, associated samples were qualified as estimated.

There were no analytes for which samples were qualified based on MS/MSD precision problems.

# Samples Collected in April 1994

Sample results for the surface water and sediment samples collected at location E3-P11-D04 on 26 April 1994 were qualified based on method blanks and control spike results. In sample WXP11043, results for barium, beryllium, copper, lead, and vanadium were qualified as estimated values as the concentrations of these compounds were above the MDL but below the RMDL. In sample DXP11043, results for antimony, beryllium, chromium, magnesium, and vanadium were qualified as estimated because the concentrations of these compounds were above the MDL but below the RMDL. The result for selenium was qualified as biased low because the standard matrix spike results were considerably below the control limits established at the laboratory.

# 2.10.2.2 Site P13 -- Massachusetts Fire Fighting Academy

Blank contamination was found for 12 different analytes in 195 samples. Analytes which were found in the method blanks included acetone, aluminum, lead, methylene chloride, potassium, sodium, and zinc. The presence of the metals can be attributed to the standard matrix or the source water used to create the blanks and methylene chloride and acetone can be considered common laboratory contamination. Aluminum, antimony, beryllium, cadmium, iron, TPHC, and zinc were detected in the rinsate blanks and were due to particulates entrained with the rinsate source water from the sampling equipment or, from the source water. TPHC is possibly due to residue on laboratory glassware and is considered an isolated case. In all cases, the samples were qualified accordingly. Methylene chloride and acetone were the only analytes detected in the trip blanks and are common laboratory contaminants.

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Other analytes were found in the method blanks but only at levels high enough to bias five samples (MX1301X1, MX1302X1, MXP13012, WX1301X1, WXP13052). Aluminum, heptachlor, potassium, sodium, and zinc were the analytes. Aluminum, cadmium, iron, magnesium, manganese, potassium, sodium, and zinc were found in rinsate blanks at levels great enough to bias 15 samples high for one or more of these analytes.

After review of duplicate RPD precision criteria, only seven samples for four analytes (aluminum, arsenic, barium, and iron) were estimated because of the results from duplicate samples.

There were no instances for which samples needed to be qualified based on MS/MSD recoveries.

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#### 3. PHYSICAL CHARACTERISTICS

Field activities described in Section 2 were used to better characterize the physical setting of the site, including the site's geologic soils, groundwater hydrology, topography, and ecology. Each of these physical characteristics are discussed in this section. Broader regional conditions are described in Volume I, Section 2.2.

#### 3.1 GEOLOGY

Site P11/P13 is located on a gently sloping terrace of glacial outwash sand and gravel, between two hills primarily of glacial till, a drumlin to the east, and a hill of ground moraine with bedrock outcrops of Gospel Hill Gneiss (Hansen 1956) to the west, formerly known as Hapgood Hill (Gallagher *et al.* 1985). Based on the interpretation of a seismic refraction survey performed in May 1993, the bedrock in the center of the site is between 140 to 170 feet AMSL, or approximately 30 to 60 feet below surface. Seismic survey lines are shown on Figure 3-1. No wells at the site were drilled more than 30 feet deep so bedrock was not encountered. A well at Site P57, 400 feet west of the site fenceline, encountered what appeared to be till at about 11 feet below surface (190 feet AMSL), and till crops out at the foot of Tuttle Hill across Puffer Road approximately 150 feet east of the site fenceline.

#### 3.2 SOILS

Soils under the site are well drained sandy soils of the Hinkley-Windsor series (Gallagher et al. 1985) or similar Merrimac soils (OHM 1992). Within the wetlands adjoining the site deeper organic soils such as Swansea muck are likely to occur (OHM 1992). Paxton soils develop on areas of till on the adjoining hills (OHM 1992). The Paxton is a well-drained loam. This soil has a clay content ranging from 3 to 12 percent, and a permeability of from 0.6 to 2 inches per hour (4 x 10⁻⁴ to 1.4 x 10⁻³ centimeters per second (cm/sec)) at up to 26 inches in depth. Below this depth, compacted tills are encountered with permeability of less than 0.2 inches per hour (4.4 x 10⁻⁴ cm/sec). Organic content ranges from 2 to 5 percent. The Merrimac soils associated with the outwash deposits are very well drained and sandy. Clay content ranges from 3 to 7 percent in the first 15 inches, but is less than 4 percent from 15 to 60 inches. Permeability ranges from 2 to 6 inches per hour (1.4 x  $10^{-3}$  to 4 x  $10^{-3}$  cm/sec) from 0 to 22 inches of soil, and up to 20 inches per hour (1.4 x  $10^{-2}$ cm/sec) from 22 to 60 inches of soil. Organic content ranges from 1 to 5 percent in the first 15 inches of soil. The Swansea (muck) is a very poorly drained soil developed in organic deposits of the swamps, bogs and marshes associated with the low-lying areas dominating the eastern side of the drumlin but scattered throughout the Annex. Clays are found only in the bottom reaches (26 to 60 inches) and can range between one to five percent. Permeability of this highly organic material runs between 0.6 to 6 inches per hour (4 x 10⁻⁴ to 4 x 10⁻³ cm/sec) to a depth of 26 inches, and greater than 20 inches per hour (1.4 x 10⁻² cm/sec) from 26 to 60 inches of soil, which is below most of the organic muck and peat. Organic content is high (greater than 50 percent) within the first 9 inches of soil.

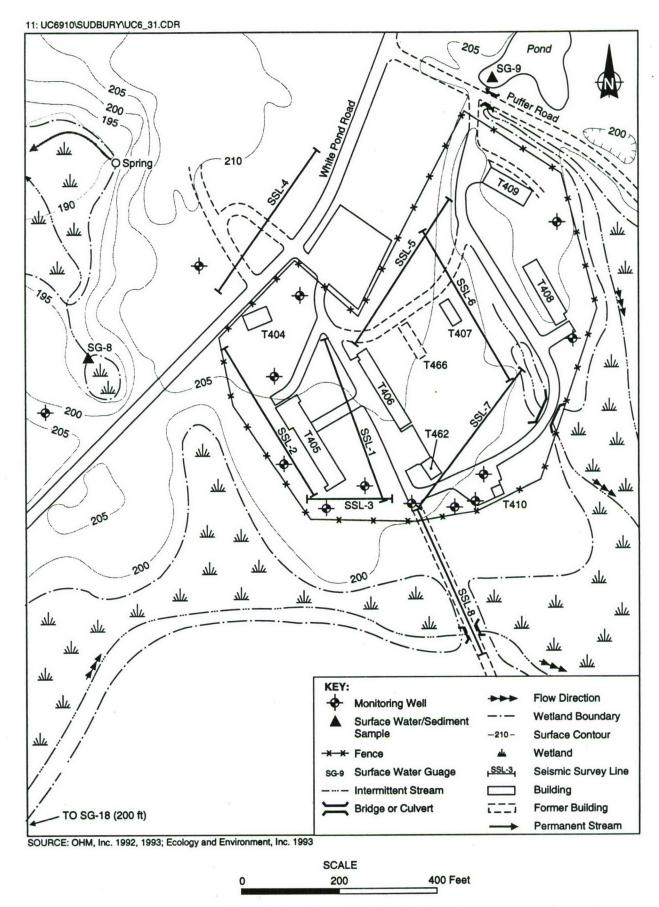


Figure 3-1 SEISMIC SURVEY LINES

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#### 3.3 GROUNDWATER HYDROLOGY

The highly permeable soils over much of the site allow for high recharge rates. The average recharge rate for the Annex south of Hudson Road was calculated at half the amount of precipitation, which averages 42 inches per year. Average recharge at Site P11/P13 can therefore be expected to be in excess of 21 inches per year because site conditions favor infiltration. The shape of the underlying water table is the result of the balance between infiltration and groundwater discharge to surface water. Known groundwater discharge areas are a spring and wetland approximately 400 feet northwest of Site P11/P13, and Honey Brook approximately 400 feet south of Site P11/P13.

The intermittent stream and the pond northeast of Building T409, and the other intermittent stream south of the site, appear to lose water to the ground, thus recharging the groundwater. The loss from the pond was immediately obvious, since the water level falls below its outlet during much of the year. The loss of water from the intermittent stream south of the site was inferred from the configuration of the water table reported in the seismic survey performed in May 1993 (Appendix E). This showed that the water table under the stream was at an estimated elevation of greater than 194 feet AMSL (Seismic Survey Line-8) while within the site Seismic Survey Line-3 (SSL-3) and SSL-1 it was estimated at less than 188 feet AMSL. Water Levels in OHM-P11-33 have ranged from a high of 196.14 feet AMSL in June 1992 to a low of 193.67 feet AMSL in December 1993. Water level measurements are presented in Table 3-1. Since the surface elevation of the seismic line where it crosses the culvert over the stream is 198 feet AMSL, and the surface water, when flowing, is approximately 196 feet AMSL, then the surface water elevation is greater than groundwater elevation when the stream is running. The implication is that the stream acts as a hydraulic barrier to groundwater movement south from the site towards Honey Brook during the period of surface water flow (approximately from December to June depending on rainfall). Even after surface water ceases to flow, the wetlands along the stream must continue to be a source of recharge to groundwater. The conclusion from this is that flow of groundwater towards Honey Brook from the site is of limited duration during the year and is reversed whenever the intermittent streams south of the site are running, and for some time afterwards. Since groundwater flow from under the site cannot go south to discharge to surface water, it must go north, being unable to go east or west because of the drumlin to the east and Hapgood Hill to the west. In fact, this is a convincing reason why the spring and wetland north of White Pond Road are the source of a perennial stream which discharges north to the Assabet River. The hydraulic gradient (slope of the water table) from the southeast side of the site (near well E3-P13-M02) to the spring (at 190 feet AMSL) is approximately 6 feet in 1,800 feet (0.0033 feet/foot). The hydraulic gradient to Honey Brook is greater, approximately 8 feet in 1,400 feet, or 0.0057 feet/foot. Average gradients from well E3-P13-M04 to surface water are approximately equal to north or to south in contrast. Rates of flow depend on hydraulic conductivity as well as hydraulic gradient, and the small contrast of gradient (170 percent greater to the south at well E3-P13-M02, for example) could easily be negated by a slight difference in hydraulic conductivity.

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Table 3-1

# GROUNDWATER AND SURFACE WATER ELEVATIONS SITE P11/P13 AND VICINITY 13 SEPTEMBER 1993, 3 DECEMBER 1993, AND 27 APRIL 1994

Well	Staff Gauge	09/13/93	12/03/93	04/27/94
E3-P11-M01		193.65	194.77	
OHM-P11-32		193.81	195.06	
OHM-P11-33		193.67	194.94	
OHM-P11-34		192.90	193.96	-
ЕНА-3		192.08	196.42	
E3-P13-M01		195.29	194.51	
E3-P13-M02		197.17	196.62	
E3-P13-M03		197.34	198.09	
E3-P13-M04		193.77	194.75	-
¥	SG-18	DRY	DRY	197.2
	SG-9	DRY	DRY	198.9
	SG-4	DRY	DRY	185.3
	SG-3	DRY	189.39	187.7

Source: Ecology and Environment, Inc., 1993, 1994.

Despite the conclusion that groundwater from under the site discharges in a generally northwesterly direction, water level measurements in ten wells at and around the site indicate that a groundwater divide extends down the center of the site from well E3-P13-M03 (upgradient) to well OHM-P11-32 (downgradient). This results in all wells except well E3-P13-M03 being downgradient of at least part of the site (see Figures 3-2 and 3-3). Groundwater impacts on surface water around the site should be confined to the stream draining Watershed 3 as defined in the Phase II Site Investigations Report (E & E 1994b).

The large fluctuation in water level in well EHA-3 as measured by OHM in January 1993 (193.34 feet AMSL), and its measurement by E & E in December 1993 (196.42 feet AMSL), have created the major change in the groundwater contours. Because the reading by E & E is 2.81 feet higher than any previous reading in this well, the reading is suspect. This does not alter any conclusions of the RI. It should be noted that the well at Site P57, well E3-P57-M01, shows the lowest groundwater elevation and the lowest hydraulic gradient

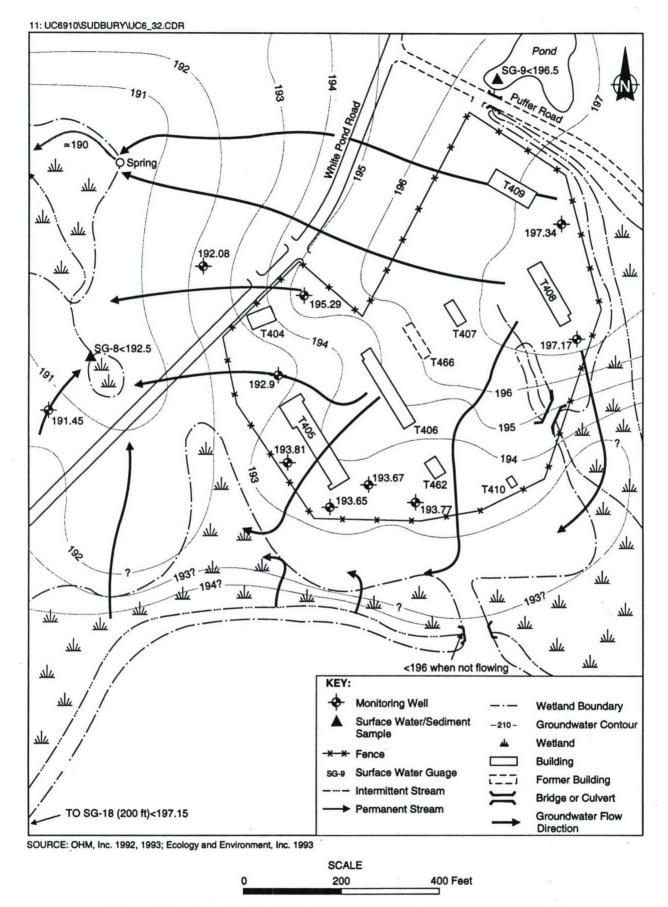


Figure 3-2 GROUNDWATER CONTOURS AND FLOW INTERPRETATION BASED ON 13 SEPTEMBER 1993 MEASUREMENTS

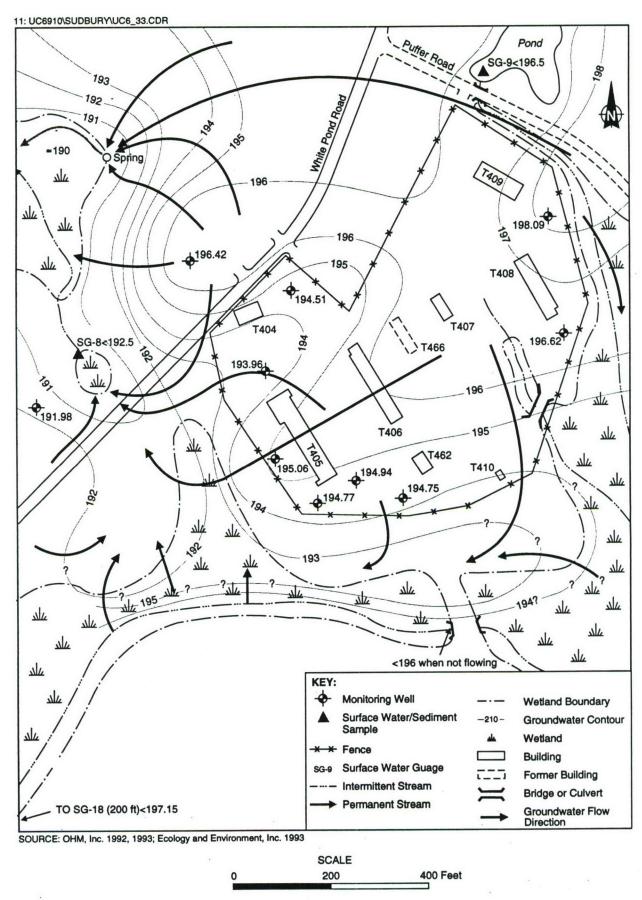


Figure 3-3 GROUNDWATER CONTOURS AND FLOW INTERPRETATION BASED ON 3 DECEMBER 1993 MEASUREMENTS

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towards the discharge in the wetland to the northeast, despite being largely screened across till. This implies that this well is close to a high hydraulic conductivity zone of the overburden which exists between wells E3-P57-M01 and well EHA-3. This zone is most likely channeling flow towards the wetland, if the bedrock hill to the west is of low hydraulic conductivity, as is highly probable.

#### 3.4 TOPOGRAPHY AND SURFACE WATER DRAINAGE

The site itself ranges from 205 feet AMSL to 208 feet AMSL along White Pond Road, and slopes down to approximately 198 feet AMSL in the wetlands south of the site.

The hills to the west and east, Hapgood Hill and the drumlin, both rise to over 300 feet AMSL and are covered with trees. There are two ponds at the foot of the drumlin which seasonally overflow to create a small intermittent stream and a wetland on the east side of the site between it and Puffer Road. A shallow swale between Buildings T407 and T408 (see Figure 3-4) drains much of Site P13 south into the wetland. Another small intermittent stream originates in a swamp approximately 1,300 feet west of Site P11 and flows east under White Pond Road where surface water gauge SG-18 is located, through a former cranberry bog to run south of Site P11/P13. It then turns south, joining the other streams draining the site, and flows down to a pond created on Honey Brook by a dam at Puffer Road. Surface water elevations (when the ponds are full and the streams are running) are approximately 197 feet AMSL upstream at SG-18; 198.9 feet AMSL at the ponds east of Site P13; 196 feet AMSL where the stream is directly south of Site P11; and 188 feet AMSL at the pond on Honey Brook (see Figure 3-4 and Table 3-1).

On the north side of White Pond Road, the wetland immediately adjacent to the road has water standing at 193 feet (SG-8), and the spring and wetland on the same drainage is at approximately 190 feet AMSL. This stream discharges to the Assabet River only 1,200 feet further north at an elevation of approximately 176 feet AMSL, just after passing SG-6. The gradient on this stream is greater than one percent, making it exceptionally steep for the Annex, although the stream at the west end of Hapgood Hill drops over 21 feet in 2,600 feet, and Marlboro Brook drops 10 feet in 1,300 feet between SG-20 and SG-19. It should be noted that, if the embankment on which White Pond Road is elevated is artificial, then the stream flowing south of the site could once have flowed directly north into Watershed 3. If this is the case, then the differences between the directions of surface water flow and groundwater flow would disappear. The earliest evidence for the existence of White Pond Road is a map of Stow dated 1830 (Gallagher et al. 1985), and there are no maps showing details of the site drainage until much later. Although the question of whether groundwater and surface water once flowed in the same direction cannot be resolved, White Pond Road appears to run in an artificial cut opposite Site P57, and on an artificial embankment between Site P57 and Site P11. It is also noticeable that the stream south of the site appears to be running in a very regular and probably artificially cut channel. This may have been cut to facilitate drainage after the Army acquired the site, just as Honey Brook was deepened and straightened to form the "diversion ditch" marked on a 1942 map of the Annex (E & E 1994a).

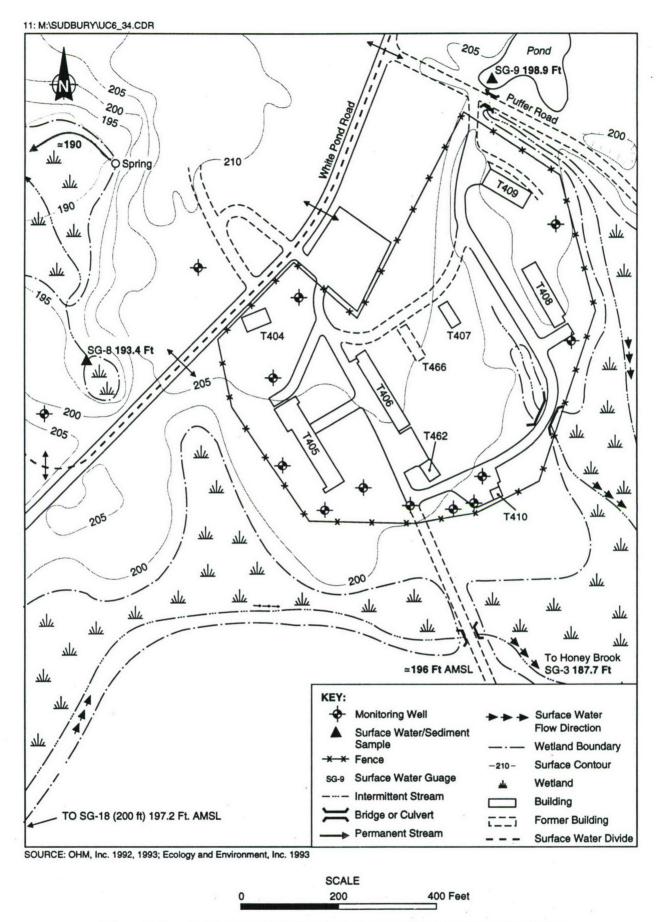


Figure 3-4 SURFACE WATER ELEVATIONS MEASURED 27 APRIL 1994 AND FLOW DIRECTIONS

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#### 3.5 ECOLOGICAL CHARACTERIZATION

The purpose of the ecological characterization is to identify, map, and describe the upland, wetland and aquatic ecosystems that occur in the vicinity of the P11/P13 site. A major objective of this ecological characterization is to determine whether or not significant ecological resources on the site or in its proximity could be impacted by site contaminants. These resources include jurisdictional wetlands and other sensitive environments; State or Federal rare, threatened, or endangered species; and economically or recreationally important fisheries or wildlife. Observations of physically stressed plants and animals, the absence of common species known to be sensitive to the type of contaminants found at the site, or any other signs indicating effects attributable to site contaminants, will also be discussed in this section. Information used to write this section was collected during an ecological field survey conducted on 22 June 1993. The methodology used during the site survey is referenced in Section 2.9 of this report.

#### 3.5.1 Cover Type Descriptions for Upland Communities

A total of five distinct cover types were identified within the area of the P11/P13 site. Four of these cover types represented upland plant communities and one was a wetland plant community. No areas of dead trees or other evidence of physical stress were observed during the June survey. The boundaries of these cover types are depicted in Figure 3-5 and the plant species identified within the study area are listed in Table 3-2. Tables 2-1 through 2-4 in Section 2, Volume I list common scientific names of birds, mammals, amphibians, and reptiles that were observed and/or are likely to occur at the Annex based on range maps (DeGraff and Rudis 1986). Table 2-5 in Section 2, Volume I lists the species of concern known to occur at the Annex. Each cover type is described in terms of plant species composition, vegetation structure, edaphic condition, and land use. The value of each cover type to wildlife is also discussed.

New England Army Corps of Engineers wetland delineation data forms were completed for each wetland cover type and are provided in Appendix K. Each wetland cover type discussed below meets the three criteria (i.e., hydrophytic vegetation, hydric soils, and wetland hydrology) necessary to be considered federally-regulated jurisdictional wetlands. In addition, data forms were completed to evaluate wetland functions and values. Table 3-3 lists the wetland functions evaluation ratings for the P11/P13 site wetlands areas. A discussion of the methodology used to determine these values is found in Section 2.9.1 of this report.

#### Cover Type 1: Open Disturbed Area

This area is located around the abandoned buildings, roads, and sidewalks in the central portion of the site and northeast of White Pond Road between two forested areas (Figure 3-5). Cover Type 1 is primarily vegetated with herbs, grasses, and shrubs, although there are also a few scattered trees and saplings. Herbaceous vegetation is dominated by

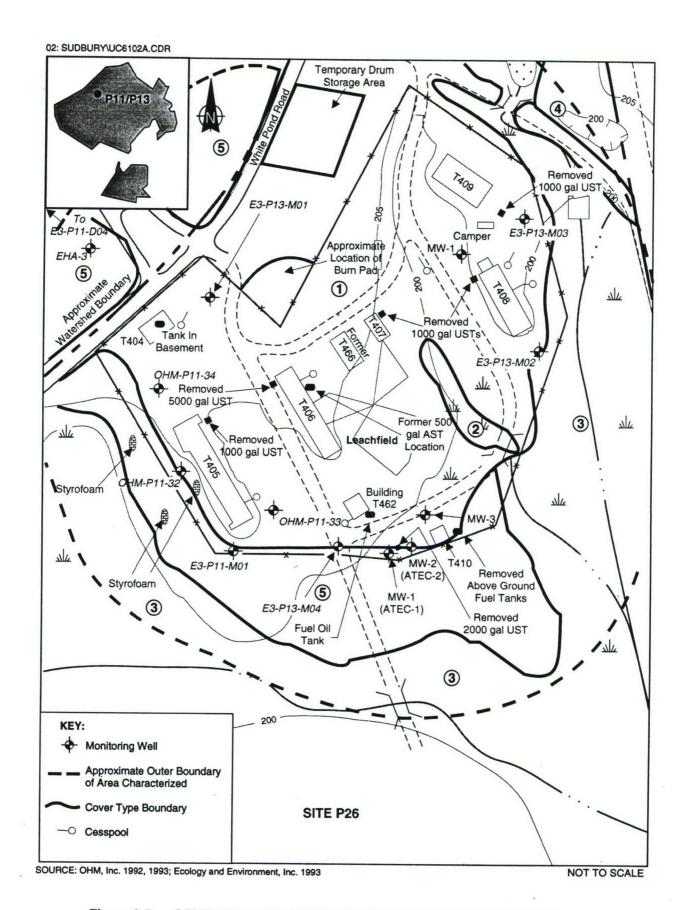


Figure 3-5 COVER MAP FOR AREAS IN VICINITY OF SITES P11 AND P13

11:UC6101/RC1286_V2-06/22/95-D2

Source: Ecology and Environment, Inc.,

Þ			Table 3-2
	SPECI	ES COMPOSITION IN THE GENE	ECIES COMPOSITION OF PLANT COMMUNITIES IDENTIFIED IN THE GENERAL VICINITY OF THE RI SITE
Cover Type	Stratum	Vegetation Density ^a	Species ^b
1. Open Disturbed Area	tree sapling shrub herb	sparse sparse sparse dense	red maple, red cedar, black locust red maple, slippery elm, white ash multiflora, rose, lowbush blueberry, poison ivy orchard grass, Kentucky bluegrass
2. Emergent Wetland	tree sapling shrub herb	sparse sparse sparse dense	none none meadowsweet, northern arrowwood, highbush blueberry sensitive fern, slender blue iris, cutgrass, cinnamon fern, tearthumb
3. Red Maple-Cinnamon Fern Forested Wetland	tree sapling shrub herb	dense sparse sparse sparse	red maple white pine, red maple none skunk cabbage, cinnamon fern, royal fern, jewelweed, sphagnum moss, highbush blueberry
4. Aspen Forest	tree sapling shrub herb	moderate moderate dense sparse	quaking aspen white pine, red oak, red maple, flowering dogwood poison ivy, Virginia creeper, rubus spp. asters, grasses, goldenrods
5. Red Maple Forest	tree sapling shrub herb	dense sparse dense sparse	red maple red maple, red oak, silky dogwood poison ivy grasses, goldenrods

^a Sparse = 0 to 30 percent area cover in the stratum. Moderate = 31 to 65 percent area cover in the stratum. Dense = 66 to 100 percent area cover in the stratum.

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^b If a dominant species was observed, only the dominant species was included in the list below.

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#### Table 3-3 WETLAND FUNCTIONS EVALUATION RATINGS FOR THE P11/P13 SITE WETLAND AREAS **Function** Wet Meadow Area Forested Wetland Score Value Score Value Biological 62 102 Low Moderate Hydrological Support 45 Moderate 58 High Groundwater Discharge 39 Moderate 47 Moderate Floodwater Storage 79 Moderate 97 High Water Quality Maintenance 68 Moderate 83 High Cultural and Economic 25 Low 53 High Recreation 22 Low 39 Moderate Aesthetic 25 Low 37 Moderate

18

Moderate

21

High

Source: Hall and McGee 1985.

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orchard grass and Kentucky bluegrass, but also includes yarrow, poverty grass, goldenrods, cinquefoil, and bedstraw. Shrubs, including multiflora rose and low blueberry, and saplings, including slippery elm, white ash, and red maple, grow around the abandoned buildings. In addition, a few red maple, black locust, and red cedar are scattered throughout the area.

This area is of low to moderate value to wildlife. The various grasses, herbs, and shrubs provide seeds and berries which can be eaten by many species of birds and small mammals. The lack of tree cover and substantial disturbance by human activity precludes the use of this area by birds for nesting, although abandoned buildings may be used by small mammals for cover and nesting.

# Cover Type 2: Emergent Wetland

Cover type 2 consists of an emergent wetland located in the eastern portion of the open/disturbed area of the site (Figure 3-5). The United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) map classifies this area as a seasonally saturated palustrine scrub-shrub/emergent wetland supporting broad-leaved deciduous vegetation (PSS1E/PEME). The NWI map indicates that the southern end of this wetland connects to a larger palustrine forested wetland (PFOIE/PSS1E) associated with the unnamed intermittent stream located on the eastern edge of the site and flowing south towards Honey Brook.

This scrub-shrub/emergent wetland is vegetated with scattered meadowsweet, highbush blueberry, and north arrowwood shrubs. The densely growing herbaceous layer consists of sensitive fern, slender blue iris, cutgrass, tear thumb, and cinnamon fern.

Scarboro muck is the underlying soil in this area and is listed by the County Soil Conservation Service (SCS) as a hydric soil (USDA 1987). Hydric characteristics observed during the soil analysis conducted in June 1993 included a low matrix chroma (black muck) with no mottles. Drainage to the southeast flows through a culvert (Figure 3-5). Wetland hydrology indicators included soil saturation in the upper twelve inches, wetland drainage pattern, shallow roots, and sediment-stained leaves.

This wetland area is of moderate-to-low value to wildlife. The size of the wetland limits the diversity and number of species it can support. The scrub-shrub/emergent wetland associated with cover type 2 provides an abundance of food (seeds and berries), a moist environment, and edge habitat; consequently attracting many species of insects, reptiles, amphibians, birds, and upland visitors such as deer.

Of the nine wetland functions evaluated in this wetland during the field survey, four were rated "low," and five were rated "moderate" (see Table 3-3). Based on this functions assessment, this wetland's primary functions include water quality maintenance and flood water storage. The educational and hydrological support are of moderate value in this wetland complex.

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#### Cover Type 3: Red Maple - Cinnamon Fern Forested Wetland

Cover type 3, a forested wetland, surrounds most of the area except for the northwestern edge of the site and is associated with two unnamed streams (one on the eastern edge of the site and the other on the southwestern edge of the site). The USFWS NWI map classifies this area as part of a larger palustrine forested wetland supporting broad-leaved deciduous trees (PFO1E). This wetland extends approximately 1,000 feet to the southwest beyond the site boundaries.

The relatively dense and immature overstory of this cover type consist almost exclusively of red maple ranging from 4 to 10 inches diameter at breast height (DBH). Some slippery elm saplings also grow in the area. The understory includes highbush blueberry, and red maple and white pine saplings. The herbaceous layer consists of skunk cabbage, cinnamon fern, royal fern, jewelweed, sphagnum moss, and grasses. No woody vines occur in this area.

Scarboro muck, the underlying soil in this wetland area, is listed by the SCS as a hydric soil (USDA 1987). Hydric characteristics observed during the soil analysis conducted in June 1993 included a low matrix chroma (black muck) with no mottles. Wetland hydrology indicators included soil saturation in the upper 12 inches, wetland drainage pattern, shallow roots, and sediment stained leaves.

Cover type 3 is considered of high value to wildlife. This red maple - cinnamon fern forested wetland extends beyond the site boundaries and supports a lush and diverse vegetation. For these reasons it is important in supporting an abundance and diversity of wildlife (Adamus *et al.* 1987). Since this wetland borders an intermittent stream it is probably the water source for wildlife in the general area. The moist conditions are attractive to a variety of amphibians such as the wood frog and northern two-lined salamander. Red maple fruits in this area provide a seasonally important food source for the eastern chipmunk, gray squirrel, and southern flying squirrel (Martin *et al.* 1951). Upland gamebirds such as the ruffed grouse and the wild turkey use maple buds, twigs and seeds and are likely to be found in this area. Songbirds like the purple finch feed on maple buds, flowers, and seeds. During the June survey, deer tracks and raccoon scats were observed in the area.

This wetland was rated as having four functions of "moderate" value and five functions of "high" value (see Table 3-3). This wetland is expected to support a moderate diversity and abundance of aquatic and terrestrial species; effectively store and gradually release storm flood waters; retain sediments and remove nutrients and thereby improve water quality; and serve as an important area for cultural, economic, aesthetic and educational uses. The presence of this wetland within the Site P11/P13 area enhances the overall ecological quality of the area.

# Cover Type 4: Aspen Forest

Cover type 4 encompasses an area northeast of the site (Figure 3-5). This forest gently slopes to the southeast and is dominated by quaking aspen trees ranging from 4 to 12

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inches DBH. Other trees species in this cover type include red oak, white pine, and shagbark hickory. The relatively dense understory consists primarily of regenerating overstory and flowering dogwood. In addition, woody vines, including poison ivy, Virginia Creeper, and rubus species, grow in the area. Grasses, asters, and goldenrods constitute the sparsely vegetated herbaceous layer.

Despite its proximity to the road, cover type 4 is expected to be of moderate to high value to wildlife. The relatively dense overstory provides an abundance of food: acorns, nuts, catkins, seeds, and berries can be eaten by many species of upland gamebirds, songbirds, and small mammals. This cover type also provides breeding and nesting areas to many species of birds and cover for large mammals such as deer (Martin *et al.* 1951).

# Cover Type 5: Red Maple Forest

Cover type 5 is located on the southern and southwestern edge of the site between the open/disturbed area and cover type 3, as well as north of the site on the northern side of White Pond Road (Figure 3-5). The dominant species in the overstory is the red maple ranging from 4 to 12 inches DBH. White pine, red cedar, slippery elm, red oak, black cherry, and white ash are other species also growing in this area. The understory is very sparse including red maple and red oak saplings and silky dogwood. The ground cover is dominated by poison ivy, but also includes grasses and asters.

This cover type is of moderate to high value to wildlife. Located on the edge of cover type 3, it is likely to support diverse wildlife. Red maple, red oak, and white pine provide and abundance of food by way of seeds and acorns attracting many species of upland gamebirds and songbirds. The dense overstory also provides valuable cover for large mammal species like deer. In addition, small mammals like the Eastern mouse, the gray squirrel, and the white-footed mouse are other likely occupants of this area (Martin et al. 1951). During the E & E June survey a wild turkey was heard in the area.

#### 3.5.2 Aquatic Resources

Surface water from the site drains to the south and southeast into two unnamed intermittent streams: one on the eastern edge of the site and one on the southern edge. The two streams converge southeast of the site and then flow towards Honey Brook. A small vernal pool referred to as North Gate Pool (Butler 1992) is located approximately 1,000 feet north of the site. This vernal pool was not characterized during the survey.

# 3.5.3 Species-of-Concern and State-Designated Estimated Habitants of Rare Wetlands Wildlife

The following are definitions of the four categories of species-of-concern as defined by the Massachusetts Natural Heritage Program (MNHESP, 321 CMR 10.03):

 Endangered: A native species in danger of extinction throughout all or a significant portion of its range and species of plants or animals

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in danger of extirpation as documented by biological research and inventory.

- Threatened: Any species of plant or animal likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and any species declining or rare as determined by biological research and inventory, and likely to become endangered in the foreseeable future.
- Special Concern: Any species of plant or animal which has been
  documented by biological research and inventory as to have suffered
  a decline that could threaten the species if allowed to continue
  unchecked or that occurs in such small numbers or with such
  restricted distribution or specialized habitat requirements that it could
  easily become threatened within Massachusetts.
- Watch List: Any species of plant or animal which has been documented by biological research or inventory to have suffered a decline or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become a species of special concern within Massachusetts.

A total of 19 species of concern have been documented within approximate 1.5-mile radius of Site P11/P13. These species include one federally-protected endangered species, one State-listed endangered species, two State-listed threatened species, four State-listed species of special concern in Massachusetts, and eleven watch-list species. These species and the approximate locations in which they were found are listed below. Species of concern discussed herein are based on studies and reports of OHM (July 1993), and references therein, Hunt (1992), Aneptek (1991), Butler (1992), correspondence with the U.S. Fish and Wildlife Service and the MNHESP, and observation during the June 1993 ecological site survey.

# **Plant Species**

A population of Midland sedge (*Carex mesochorea*), a State endangered plant species, was found on the northern edge of the site (Hunt 1992). A population of a plant species threatened in Massachusetts, Few-seeded Sedge (*Carex Oligosperma*), was found south of the site near Patrol Road and within a 1.5-mile radius of Site P11/P13 (Hunt 1992).

Several Massachusetts watch list plant species are in the northern part of the Sudbury Annex: Small beggar ticks (*Bidens discoidea*) were identified approximately 300 feet northeast of the site; Lacegrass (*Eragrostis capillaries*) was found on artificial sand mounds within the site boundaries; Blazing Stars (*Liatris Borealis*) were observed approximately 1,200 feet north of the site; Stands of Red Pine (*Pinus resinosa*) were documented in two locations; and a population of Northern Starwort (*Stellaria calicantha*) was seen approximately 2,500 feet east of the site (Hunt 1992).

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Grass-leaved Ladies' Tress (Spiralis vernalis), a species of special concern in Massachusetts, was identified in the unmowed field in the Taylor Drop Zone located south of Site P11/P13 (Aneptek 1991). Wood Witchgrass (Panicum philadelphicum), another species of special concern, was observed in the western part of the Annex within a 1.5-mile radius of the site (Hunt 1992).

#### **Avian Species**

During the winter 1990, a pair of federally protected Bald Eagles (Haliaeetus leucophalus) was observed for two consecutive days in the trees along the forest edge of the Taylor Drop Zone, approximately 400 feet south of the site (Aneptek 1991). The redshouldered hawk (Buteo lineatus), a Massachusetts watch list species, was observed on a dead oak on the western edge of the Taylor Drop Zone, approximately 400 feet south of the site (Aneptek 1991). The Eastern Bluebird (Sialis sialis) and the Purple Martin (Progne subis), two Massachusetts watch list species, were observed by residents of the Capehart housing area within 1.5 miles of the site, more specifically on the southern part of the Annex (Aneptek 1991). In November 1993, a Great Blue Heron (Ardea herodias) and an Osprey (Pandion haliaeetus) were observed in the Puffer Pond Area, approximately 4,000 feet southeast of the RI site.

# Reptile and Amphibian Species

Spotted Turtles (Clemmy gutata), a species of special concern, were found at three locations on the Annex, all within a 1.5-mile radius of the site. Blue Spotted Salamander, another species of special concern in Massachusetts, (Ambystoma laterale) eggs were noted in a vernal pool approximately 2,500 feet southwest of the site. A state watch list species, Spotted Salamander (Ambystoma maculatum), was observed approximately 2,000 feet southwest of the site (Butler 1992). Finally, a Blanding's Turtle (Emydoidea blandingii) was observed at the Annex within a 1.5-mile radius of the site (OHM 1993).

# State-Designated Habitat of Rare Wetlands Wildlife

The MNHESP identifies wetland areas considered to be suitable habitats for species of rare vertebrate and invertebrate animals that use wetlands for foraging, breeding, and/or nesting. These estimated habitats of State-listed habitats are regulated under the Massachusetts Wetlands Protection Act Regulations. No unique habitats have been identified in the general vicinity of the site (MNHESP 1992).

#### 3.5.4 Discussion

Although the area within the site boundaries has been disturbed by human activity, it is considered of moderate ecological quality due to the presence of a variety of upland and wetland communities. The combination of open, forested, emergent wetland, and forested wetland areas provide enough food and cover to support a diverse array of wildlife. In addition, the two intermittent streams that border the site on its eastern and its southwestern

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sides contribute to the importance of this area by providing a drinking source for wildlife and maintaining the nearby wetlands.

The wetland areas near the site include three different types of communities: forested wetland, emergent wetland, and open water intermittent stream and vernal pool. Forested and emergent wetlands combine several woody and emergent plant species to provide an abundance of food and cover, consequently attracting many kinds of wildlife species. Open water areas such as North Gate Pool and intermittent streams constitute valuable environments that attract many species of insects, reptiles, amphibians, birds, and upland wildlife.

Nineteen species of concern have been documented within a 1.5-mile radius of the site and most of them were in fact identified less than a few hundred feet away from the site. Two species of concern, namely Midland sedge (*Carx mesochorea*) a State endangered species, and Lacegrass (*Eragrostis capillaries*), a Massachusetts watch list species, were observed within the boundaries of the site (Hunt 1992). No State-designated habitats of rare wetland wildlife exist within a 1.5 mile radius of the site.

No signs of physically stressed vegetation other than the effects due to clearing activities were observed on the site. The cleared areas appear to be revegetating and a relatively high diversity and abundance of terrestrial wildlife was observed in the nearby forested areas and wetland areas suggesting that the site contaminants are not currently affecting local terrestrial species or at least not to a significant degree.

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#### 4. NATURE AND EXTENT OF CONTAMINATION

This section discusses the potential sources of chemical contamination associated with the site, the nature and extent of contamination indicated by field investigation and sampling efforts, and concludes by relating the sample analysis results to the potential sources. Location of sampling points are identified on the Plate enclosed at the back of this volume, with the exception of two surface water and sediment sampling locations which are downgradient of the site. These locations are shown on the Plate at the end of Volume I. Detections above background in surface soils, subsurface soils, groundwater, surface water, and sediments are noted in Tables 4-1 through 4-6 in Section 4.2.5. Chemical summary reports for subsurface soil sampling (Table 4-7), groundwater sampling (Tables 4-8 and 4-9), surface water sampling (Table 4-10) and sediment sampling (Table 4-11) are enclosed at the end of Section 4.3 below.

#### 4.1 POTENTIAL SOURCES

Due to the variety of past activities that have taken place at the site, this section describes the operations at locations that could have been potential sources of contamination. In the paragraphs to follow, a description of each activity is provided along with any other information that may indicate potential contaminant sources. The information presented was drawn primarily from the Master Environmental Plan (MEP) (E & E 1994a) and the Phase II SI report (E & E 1994b). Additional information has been gleaned from various Army files that have been made available to interested parties.

#### 4.1.1 Ordnance Research and Development (1952 to 1957)

From 1952 to 1957, Buildings T405 to T409 were used for ordnance (explosives) research and development. A 1955 facility map identified Building T405 as the "barricade" building, Building T406 as the "power plant", Building T408 as the "surveil" building and Building T409, as the "asses & pack" (presumably assembly and packaging of material) building. The exact nature of this research was not identified from available documents. Potential contaminants could include explosives and ordnance constituents.

#### 4.1.2 Research Activities in Building T405 (1958 to 1982)

Building T405 was the center of much of the laboratory research conducted by Natick Laboratories between 1957 and 1982. General research activities included laboratory research on foamed plastics, organic chemicals, flame testing, and insecticide and rodenticide research. In 1962, chemicals including acetone, benzene, methanol, MEK, peroxide, and toluene were noted as being stored at the Annex for use at Building T405. Decontamination water from cleaning spray equipment went into 5-gallon cans and 55-gallon drums. Spray heads were cleaned by spraying them out into the air. During that same year, AEHA identified the use of

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toluene-2,4-diisocyanate, amine hardeners, MEK, and peroxide in the building. Sometime during the early to mid-1960s, Building T405 was also the location of defoliant, rodenticide, and insecticide research. The Clothing Equipment and Material Engineering Laboratory (CEMEL), a division of Natick Laboratories, also used portions of the building to mix chemicals. High pressure and high temperature equipment was recorded as being installed in the building and used for studying organic synthetic reactions at high pressure (NARADCOM 1978). Potential contaminants from these activities could include volatile organics and solvents, flammable liquids, and pesticides.

# 4.1.3 Alleged Chemical Disposal Near Building T405 (1960s)

According to an interview with a Natick Laboratory employee, chemical disposal may have occurred along the fence located west of Building T405 (Interview 1990). If this activity occurred, the likely source of the disposed chemicals is the research activity conducted in Building T405 during the 1960s. Potential contaminants from these activities could include volatile organics and solvents, flammable liquids, and pesticides.

# 4.1.4 USTs and ASTs Associated with Buildings at the Site (1952 to 1992)

Six USTs and several ASTs were previously connected to buildings at the site. The USTs were removed in 1992, and removal of contaminated soil occurred at several of the USTs. The ASTs located at Buildings T406 and T410 were also removed in 1992. The AST at Building T462 is still attached to the building. Potential contaminants from these sources include petroleum and gasoline, and metals from the galvanized steel of the tanks.

#### 4.1.5 Gasoline Station Operations at Building T410 (1962 to late 1980s)

By 1962, the area around Building T410 was converted to use as a gas station with gas pumps located in front. As of 1978, a gas pump was still being used by the MFFA. In addition to potential leaks from the UST and the ASTs at Building T410, gas station activities could have resulted in spills of gasoline or waste oil in the area.

# 4.1.6 Transformer Associated with Building T406 (1952 to Present)

A transformer attached to northern side of Building T406 may be the source of PCB contamination. The capacity of the transformer is 15 kilo-Volt-Amperes (kVA). The first designation of Building T406 during the MOTS period was as some kind of "power plant", and the transformer was probably installed in relation to this use.

# 4.1.7 Fire Training Activities in the Parking Area by the MFFA (1971 to 1991)

Training activities in the parking area north of Buildings T406 and T407 by the MFFA included flammable liquid fire training, firetruck driver training, and car fire training. Car fire training was conducted approximately five times a year with the gasoline tanks removed and straw used as the combustible material. Flammable liquid fire training was

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conducted approximately 12 times a year in a pan apparatus using fire extinguishers; the 500-gallon fuel storage trailer was used in connection with the pan fires.

Poor housekeeping practices by the MFFA took place in 1986 according to Fort Devens personnel who observed dead grass and stains surrounding the fuel storage trailer and burn pan. At the time, the burn pan was observed to be filled nearly to capacity with a mixture of fuel and water. However, by 1991, the pan had a plywood cover to keep out rainwater, and a second pan was located below the burn pan to contain any spills. Potential sources of contamination from these activities include petroleum or other fuels used in flammable liquid fire training, fuels that may have leaked from the 500-gallon fuel storage trailer, and leaks or spills from the burn pan used during fire training, in addition to polynuclear aromatic hydrocarbons (PAHs) or metals from car fire and other fire training.

## 4.1.8 Summary of Sources

Ordnance research at Buildings T405, T406, T408, and T409 could be a potential source of explosives. The research activities performed at Building T405 and the alleged disposal of chemicals in the area west of Building T405 could be potential sources of solvents or other volatile organic compounds, flammable liquids, and pesticides. Leaks from USTs or ASTs at the site and gasoline station operations at Building T410 could be a source of petroleum contamination. Fire training activities by the MFFA could be the source of PAH, metals, and petroleum contamination. The transformer located at the north end of Building T406 and spills of waste oils could be sources of PCBs.

General site sources include pest management practices that may have resulted in residual amounts of pesticides in soils at the site, and vehicle traffic and parking which could result in oil leaks into soils at various points at the site.

#### 4.2 NATURE AND EXTENT OF CONTAMINATION

## 4.2.1 Surface Soils

The scope of the field investigation did not include the collection of any surface soil samples. Thus, this section is based on a review of the analytical results for sampling conducted by OHM, Inc. during their prior investigation at the site. The surface soil samples were compared with the background levels established through E & E background sampling, so as to provide consistency throughout this report. OHM collected surface soil samples at the site for four reasons: to investigate potential contamination associated with four removed drums, two found north of Building T409 (sample locations P13CD1 and CD2), one found north of White Pond Road across from Building T404 (P13CD3), and one found west of Building T405 (P11CD1); to investigate potential petroleum contamination associated with existing and removed ASTs at Building T410 (P13CA1/CA2/CA3/CA4), Building T462 (P13CA5 and CA6), and Building T406 (P13CA7 and CA8); and to investigate potential contamination associated with the MFFA burn pan located in the south corner of the parking area (P13S01/S02/S03).

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While metals were found at concentrations above background in many samples, most of the detections of metals including all of those for aluminum, arsenic, cobalt, iron, lead, and mercury were either below or only slightly above the background level. Of those metals found in concentrations in at least one sample at a concentration more than twice the background levels, the highest detections were found in just three samples. Most of the highest detections were in one of the samples from the burn pan area (P13S01) including those for barium (252  $\mu$ g/g); cadmium (14.2  $\mu$ g/g); calcium (6,030  $\mu$ g/g); chromium (42.7  $\mu g/g$ ); magnesium (8,260  $\mu g/g$ ), potassium (4,340  $\mu g/g$ ), sodium (577  $\mu g/g$ ), vanadium (109  $\mu g/g$ ), and zinc (910  $\mu g/g$ ). The highest detections for copper (550  $\mu g/g$ ) and nickel (30.9)  $\mu g/g$ ) were found in the sample (P13CA7) collected at the former location of the 500 gallon AST just northeast of Building T406. The highest detection of manganese (460  $\mu$ g/g) was found in one (P13CA1) of the samples collected at the former AST locations east of Building T410. Potassium and manganese were found consistently above background in most of the samples. Given the diversity of sample locations, these detections of potassium and manganese are more likely to indicate natural levels than any site-wide contamination. Metals contamination was not indicated by the drum confirmation sample results. The pattern of detections suggest some limited low-level metals contamination at the former AST locations near Buildings T406 and T410, and the existing AST at Building T462, which is likely due to deterioration of the steel ASTs. The detections at P13S01 seem to indicate some residual low-levels metals contamination in the area of the burn pan. Given that car fire training was done in the parking area by MFFA, the vehicles burned could be a potential source of the metals. Table 4-1 summarizes the detections above background at the site.

PCBs were only found in three of the fifteen soil samples collected at the site. Two of these samples (P13CA7 and P13CA8) were collected near the former location of the Building T406 AST. However, these samples are also close to the transformer located on the north side of Building T406. PCBs were found in these samples in the form of PCB 1254 with detections ranging from 0.61  $\mu$ g/g to 3.4  $\mu$ g/g. PCB 1260 was also detected in one sample (P13CA3) collected at the former AST locations just east of Building T410 at 0.455  $\mu$ g/g. It is important to note that some waste oils will contain PCBs, and this is another potential source of PCBs at the site.

Dichlorodiphenyltrichloroethane (DDT) and its degradation products dichlorodiphenyldichloroethylene (DDE) and dichlorodichloroethane (DDD) were found in several samples above background soil levels. The concentrations of DDT (1.1  $\mu$ g/g, maximum), DDD (0.59  $\mu$ g/g, maximum), and DDE (0.84  $\mu$ g/g, maximum), and of other pesticides detected were sufficiently low to suggest their source is general pest management practices rather than any large-scale spills or dumping of pesticides. Other pesticides found in several of the surface soil samples include:  $\alpha$ -chlordane (0.35  $\mu$ g/g, maximum),  $\gamma$ -chlordane (0.46  $\mu$ g/g, maximum), and heptachlor epoxide (0.16  $\mu$ g/g, maximum). Heptachlor (at 0.020  $\mu$ g/g),  $\beta$ -Endosulfan (at 0.29  $\mu$ g/g), and dieldrin (0.0413  $\mu$ g/g) were also detected above background but only in one of fifteen samples. Elevated levels of pesticides were primarily found in two areas: near the burn pan in the parking area (at location E3-P13-S01), and at the former location of the 500 gallon AST at Building T406 (locations E3-P13-CA7 and E3-P13-CA8).

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	Table 4-1	
ANALYTES DETECTED	IN SURFACE SOIL	ABOVE BACKGROUND (μg/g)

Compound	Frequency Detected ¹	Maximum Concen- tration	Site ID	Maximum in Background	Frequency Above Background
Aluminum	15/15	14,000	P13S01	10,400	3/15
Arsenic	15/15	11	P13CA3	10	1/15
Barium	15/15	252	P13S01	25.1	7/14
Cadmium	15/15	14.2	P13S01	< 0.5	14/15
Calcium	13/15	6,030	P13S01	1,170	3/15
Chromium	15/15	42.7	P13S01	14.2	10/15
Cobalt	13/15	10.7	P13CA1	6.1	3/15
Copper	15/15	550	P13CA7	10.7	11/15
Iron	15/15	24,000	P13S01	12,300	3/15
Lead	15/15	180	P13CA7	150	2/15
Magnesium	15/15	8,260	P13S01	2,310	7/15
Manganese	15/15	460	P13CA1	95.8	13/15
Mercury	4/15	0.426	P13CA7	0.318	1/15
Nickel	15/15	30.9	P13CA7	10.7	7/15
Potassium	15/15	4,340	P13S01	617	12/15
Sodium	1/14	577	P13S01	<200	1/14
Vanadium	15/15	109	P13CA7	33.0	2/15
Zinc	14/15	910	P13S01	44.6	6/15
Methylene chloride	1/15	0.014	P13CA8	-	1/15
Toluene	1/15	0.0039	P13CA2		1/15
1,1,1 Trichloroethane	1/15	0.0016	P13CA6	-	1/15
Trichlorofluoro methane	1/15	0.012	P13CA6		1/15
DDT	15/15	1.1	P13CA8	0.233	6/15
DDD	3/15	0.59	P13S01	0.063	2/15
DDE	9/15	0.84	P13CA7	0.139	4/15
α-Chlordane	4/15	0.35	P13CA7	0.004	4/15
γ-Chlordane	4/15	0.46	P13CA7	0.005	3/15
Heptachlor	1/15	0.0202	P13CA7	ND	1/15
Heptachlor epoxide	4/15	0.16	P13S01	0.006	4/15
β-Endosulfan	1/15	0.29	P13S01	0.004	1/15
Dieldrin	1/15	0.0413	P13CA7	0.023	1/15
PCBs	. 3/15	3.4	P13CA7	ND	3/15
2-Methyl naphthalene	1/15	2.61	P13S01	-	

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		Table	4-1		
ANALY	TES DETECTE	IN SURFACE	SOIL ABOVE	BACKGROUND (	μg/g)
Compound	Frequency Detected ¹	Maximum Concen- tration	Site ID	Maximum in Background	Frequency Above Background
Acenapthene	1/15	0.747	P13S01		
Bis(2-ethyl hexyl)phthalate	3/15	18.3	P13S01		
Chrysene	1/15	2.42	P13S01		
Di-n-octyl phthalate	1/15	1.49	P13S01		-
Phenanthrene	1/15	2.11	P13S01		
Pyrene	1/15	3.54	P13S01		

¹ All samples are OHM samples as follows: P13S01/S02/S03; P13 CA1/CA2/CA3/CA4/CA5/CA6/CA7/CA8; P13CD1/CD2/CD3; P11CD1

Source: Fort Devens Sudbury Training Annex Final SI/RI Report, OHM, Inc, 1994

One explosive compound, 2-nitrotoluene, was detected in the P13CA5 sample taken near the Building T462 AST, but this detection was unconfirmed. Trace levels of several volatile organic compounds were detected in single samples including methylene chloride  $(0.014 \ \mu g/g)$ , toluene  $(0.0039 \ \mu g/g)$ , 1,1,1 trichloroethane  $(0.0016 \ \mu g/g)$ , and trichlorofluoromethane  $(0.012 \ \mu g/g)$ . Trace levels of MEK  $(0.0031 \ \mu g/g)$  were found in the P13CA5 sample but were not found in the duplicate sample, and 1,1,1 trichloroethane  $(0.0017 \ \mu g/g)$  was found in the duplicate of this sample, but not in the sample itself.

PAHs, including 2-methylnaphthalene, acenapthene, chrysene, phenanthrene, and pyrene were only found in the P13S01 sample collected near the burn pan area. Given that fire training was conducted in this area, the presence of PAHs is consistent with that activity. PAHs were not found in the other two samples taken near the burn pan or in any other surface soil samples taken at the site. Bis(2-ethylhexyl)phthalate was found in low levels (up to  $1.6~\mu g/g$ ) in two of the drum confirmation samples and at a higher level ( $18~\mu g/g$ ) in the P13S01 sample. Di-n-octyl phthalate was also found at a low level ( $1.49~\mu g/g$ ) in the P13S01 sample.

## 4.2.2 UST Content Sampling by ATEC, Inc.

The contents of two of the removed USTs were sampled by ATEC, Inc. and analyzed to confirm that they contained only fuel oil. The Building T406 UST, a 5,000 gallon tank for No.2 fuel oil, contained the following semivolatile compounds: acenapthene, acenapthylene, anthracene, fluoranthene, naphthalene, di-n-butyl phthalate, and 2-methylnaphthalene. The Building T408 UST, a 1,000 gallon tank for No. 2 fuel oil, contained benzene, toluene, ethylbenzene, xylenes, acenapthylene, 2-methylnaphthalene, isophorone, and PCE ( $16 \mu g/g$ ) and 2,6 dinitrotoluene ( $745 \mu g/g$ ). Except for the PCE and the dinitrotoluene, the compounds detected are consistent with fuel oil use.

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# 4.2.3 UST Subsurface and Groundwater Sampling by ATEC, Inc., and OHM

At the Building T405 UST, no soil staining or discoloration was noted during the excavation by ATEC. Field screening and analysis with a NDIR revealed TPHC ranging from 7.5 to 63.1 ppm. Laboratory analysis of two soil samples collected by ATEC indicated no detectable TPHC in the wall of the excavation and a TPHC concentration of 23  $\mu$ g/g in the bottom of the excavation. OHM sampling from the excavation (P13CU2) indicated TPHC up to a maximum concentration of 13  $\mu$ g/g collected from the bottom of the excavation.

At the Building T406 UST, no soil staining or discoloration was noted by ATEC in the excavation area. NDIR analysis of soil samples from the excavation ranged from 7.2 ppm to 48.0 ppm of TPHC. Laboratory analysis of two soil samples collected by ATEC from the UST excavation did not contain detectable levels of TPHC. The subsurface soil sample collected by OHM (P13CU1) at the Building T406 UST did not contain TPHC, but did contain a trace amount of toluene (.0023  $\mu$ g/g).

At the Building T407 UST, soil was noted by ATEC to be stained and discolored in the excavation area. Field screening of soil samples by ATEC with an NDIR from the excavation of the Building T407 UST indicated levels of TPHC ranging from 3.2 ppm to 287.2 ppm. Laboratory analysis of two samples indicated TPHC concentration of  $16~\mu g/g$  in the excavation wall and  $19~\mu g/g$  in the bottom of the excavation.

At the Building T408 UST, soil was noted by ATEC to be stained in the excavation area. Initial sampling indicated that soils contained between 23 to 56  $\mu$ g/g of TPHC. Groundwater was encountered during the excavation of the UST at Building T408 at a depth of 4.5 feet BGS. One sample was collected from the groundwater in the excavation and analysis indicated 32,000  $\mu$ g/L of TPHC. A total of over 28 tons of soil were then removed and subsequent soil sampling from the excavation indicate residual levels of TPHC ranged from 20 to 27  $\mu$ g/g. NDIR field screening of soil samples from the boring for the monitoring well installed by ATEC at Building T408 indicated TPHC concentrations ranging from 3.4 to 10.4 ppm. One groundwater monitoring well (MW-1) was then installed approximately 37 feet northwest of Building T408 and 25 feet northwest of the UST excavation site to a depth of 12 feet BGS. It should be noted that this well is probably upgradient of the former UST location. Analysis of the groundwater sample did not indicate TPHC.

At the Building T409 UST, soil was noted by ATEC to be stained in the excavation area. Laboratory analysis of soil from the excavation indicated soil contained between 61 and 137  $\mu$ g/g of TPHC. Groundwater was encountered during the excavation at a depth of 8 feet BGS. One sample was collected from the groundwater in the excavation and analysis did not detect TPHC. Approximately 50 tons of soil was subsequently removed. Laboratory analysis of post-remedial soil samples indicated TPHC between 11 and 63 ppm.

At the Building T410 UST, a petroleum odor and soil staining were observed by ATEC in the tank excavation area. Laboratory analysis of two soil samples from the excavation indicated TPHC concentrations up to  $12 \mu g/g$ . Groundwater was encountered during the ATEC excavation of the UST at Building T410 at a depth of 6 feet BGS. One

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sample was collected from the groundwater in the excavation and analysis indicated 24,000  $\mu$ g/L of TPHC. Over 140 tons of gasoline-contaminated soil were removed from the tank area. Post-remedial soil samples from the excavation contained TPHC concentrations ranging from 11 to 187  $\mu$ g/g. Subsequent NDIR field screening of subsurface soil samples from three wells installed by ATEC indicated TPHC concentrations ranging from 16.4 ppm to 322.1 ppm. Three groundwater monitoring wells were then installed each to a depth of 16 feet BGS. MW-1 was installed 20 feet west of the UST. MW-2 was installed 15 feet south of the UST excavation. MW-3 was installed 20 feet northeast of the UST excavation. The three wells were sampled in November 1994 and analyzed for TPHC. MW-3 was also analyzed for VOCs. No TPHC and no VOCs were detected in any of the ATEC samples.

#### 4.2.4 Subsurface Soils

The scope of the field investigation for this report did not include the collection of any subsurface soil samples, except geotechnical samples collected from borings for the newly installed wells to characterize the nature of subsurface soils. The results of geotechnical sampling are discussed in Section 3. The results of subsurface soil sampling by ATEC and OHM are discussed below as they relate to the nature and extent of contamination at the site. Since no subsurface background samples were collected the subsurface soils samples are compared to surface soils background. Subsurface soil samples were collected by ATEC during the removal actions at six USTs at the site, and by OHM during the excavation of two of the USTs and these results were discussed in Section 4.2.3 above. ATEC also performed two soil borings in the vicinity of Building T405 to investigate potential pesticide contamination. OHM also excavated two test pits in the area west of Building T405, and collected subsurface soil samples from these test pits and from the borings conducted for the installation of three monitoring wells.

Subsurface soil samples from the two borings conducted by ATEC in the area east of Building T405 in the vicinity of the removed Building T405 UST, were collected and analyzed for pesticides only. No pesticides were detected in these borings.

OHM, as part of their SI, excavated two test pits and collected subsurface soil samples in the area west of Building T405 to investigate the alleged disposal of chemicals in this area. The location of these two test pits was chosen based on the highest soil gas detections found in an earlier soil gas investigation by OHM in the area around Building T405. No volatile or semivolatile organic compounds and no pesticides were detected in subsurface soil samples from these test pits. The only metals found at levels above background for surface soil were barium, cadmium, and potassium. The highest barium detection (28.3  $\mu$ g/g in test pit P11TPB) was only slightly above the background level of 25.1  $\mu$ g/g. Potassium was elevated above surface soil background in all of the subsurface soil samples collected and probably reflects natural concentrations. Cadmium was elevated in the test pit samples above surface soil background at a depth of 2 feet in both P11TPA (7.72  $\mu$ g/g) and P11TPB (13.1  $\mu$ g/g).

OHM also collected subsurface soil samples from the borings for three monitoring wells installed by OHM around Building T405. The only metals found elevated above surface

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soil background levels were cadmium (in OHM-P11-32 at  $0.706~\mu g/g$ ), copper (in OHM-P11-32 at  $16.1~\mu g/g$ ), iron (in OHM-P11-32 at  $16,000~\mu g/g$ ), manganese (in OHM-P11-34 at  $120~\mu g/g$ ), and potassium (in all three wells OHM-P11-32, 33, and 34 up to  $1,050~\mu g/g$ ). All of these metal detections were only slightly above background levels and are unlikely to indicate any site-related contamination. No volatile or semivolatile organic compounds, pesticides, or PCBs were positively detected in OHM samples from these three borings. Table 4-2 presents the maximum concentration values and frequency of detection above background for analytes in subsurface soils.

### 4.2.5 Groundwater Sampling Results

Groundwater sampling has been conducted at the site by AEHA in 1983, ATEC in 1992, OHM in 1992, and E & E in 1993. AEHA installed the EHA3 well in 1983 northwest of the site area across White Pond Road to a depth of 28.5 feet BGS and subsequently sampled the well. Analysis of the AEHA sample indicated only nitrite and nitrate as nitrogen at 3  $\mu$ g/L. Groundwater samples were collected by ATEC when groundwater was encountered during the excavation of the USTs at Buildings T408, T409, and T410. ATEC also installed and sampled three wells (MW-1,2,3) in the vicinity of Building T410, and one well in the vicinity of Building T408 (MW-1). All ATEC wells were installed to a depth of 16 feet BGS with the exception of MW-1, which was installed to a depth of 12 feet BGS. The results of ATEC groundwater sampling are discussed in Section 4.2.3. OHM installed and sampled three wells (OHM-P11-32/33/34) in the vicinity of Building T405, and also sampled the EHA3 well in connection with the investigation of the alleged chemical disposal area west of Building T405. The OHM-P11-32 and 33 wells were installed to a depth of 15 feet BGS, and the OHM-P11-34 well was installed to a depth of 18 feet BGS. E & E installed and sampled five wells (E3-P11-M01, E3-P13-M01/M02/M03/M04) and sampled five additional wells (OHM-P11-32 and 33, ATEC MW-1 and 2 at Building T410, and EHA3) to investigate groundwater contamination at the entire site. The E3-P11-M01 well was installed to a depth of 16 feet, the E3-P13-M01 and E3-P13-M04 wells were installed to a depth of 19 feet BGS, and the E3-P13-M02 and E3-P13-M03 wells were installed to a depth of 18 feet BGS. The OHM and E & E sample results are described below in the context of the entire site and all potential sources.

Analysis of groundwater sampling by OHM and E & E of the network of 11 monitoring wells installed by AEHA (1 well), ATEC (2 wells), OHM (3 wells), and E & E (5 wells) enables characterization of upgradient, on-site, and downgradient groundwater conditions. Review of the data from the geophysical study, water elevation measurements, and hydraulic conductivity testing allowed the development of groundwater flow and contour maps for the site (see Section 3). As described in Section 3, the E3-P13-M03 well installed in the northeast corner of the site in an area southeast of Building T409 and northeast of Building T408 is hydrogeologically upgradient of the site buildings and any potential sources located at the site. The groundwater flow at this point is westerly or southwesterly from well E3-P13-M03. Analysis of samples from the E3-P13-M03 well provides a characterization of local groundwater background conditions, as there is no groundwater drainage from the site to this well and groundwater drains away from this well to the south, southwest, and west.

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ANAI VTES D	ETECTED IN SI		able 4-2 OIL ABOVE SURFA	CE SOIL BACK	CPOUND (ug/g)
Compound	Frequency Detected ¹	Maximum Concen- tration	Site ID (Depth BGS)	Maximum in Background	Frequency Abov Background
Barium	5/7	28.3	P11TPB (2 ft BGS)	25.1	1/7
Cadmium	5/7	13.1	P11TPB (2 ft BGS)	<0.5	5/7
Copper	7/7	16.1	OHM-P11-32	10.7	1/7
Iron	7/7	16,000	OHM-P11-32	12,300	1/7
Manganese	7/7	120	OHM-P11-34 (2 ft BGS)	95.8	3/7
Potassium	7/7	2130	P11TPB (2 ft BGS)	617	7/7
Toluene	1/5	0.0023	P13CU1 (10 ft BGS)		
TPHC	1/2	13	P13CU2 (8 ft BGS)		

¹ All samples are OHM samples from the following locations: OHM-P11-32, OHM-P11-33, OHM-P11-34, P11TPA (1 sample for metals, 2 for VOCs); P11TPB (1 sample for metals, 3 samples for VOCs), P13CU1, P13CU2; only samples analyzed for TPHC were P13CU1 and P13 CU2

Source: Fort Devens Sudbury Training Annex Final SI/RI Report, OHM, Inc, Jan. 1994

Sample analysis results from the local background well indicated no detectable concentrations of any organic compounds, pesticides, or herbicides. TPHC was detected in one of two rounds at 332  $\mu$ g/L. Given that the E3-P13-M03 well is downgradient of Puffer Road, it is possible that this TPHC detection may be related to road runoff. Metals in unfiltered samples were often elevated above those in filtered samples due to the presence of suspended solids. As a means of comparison, in unfiltered samples, aluminum (up to 5,440  $\mu g/L$ ), iron (up to 6,600  $\mu g/L$ ) and manganese (210  $\mu g/L$ ), exceeded the Massachusetts Secondary Maximum Contaminant Levels (MCLs) for aesthetics and taste, and sodium (up to 42,200 μg/L) exceeded the EPA Drinking Water Health Advisory level. These detections however varied dramatically between the two sampling rounds in August and November of 1993, reflecting natural fluctuations in concentrations of these metals. Filtered samples also contained iron, manganese, and sodium above these standards. Despite these exceedances, given the location of the well and the nature of these detections, these metals are unlikely to indicate contamination and are indicative of local background conditions. However, given that this is only one data point and that this well was only sampled twice, the actual natural fluctuation of metal concentrations could differ from the concentrations found in the E3-P13-M03 well.

For metal concentrations, EPA guidance requires human health risk assessments regarding inorganic analytes in groundwater to be conducted using unfiltered groundwater

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sampling data. Thus, in Section 6, the risk assessment has been conducted using the unfiltered groundwater data as well as the filtered data. As indicated by sampling of the local background well, the elevated concentrations of metals in unfiltered samples is due to the presence of suspended solids. Migration of metals through subsurface media, however, primarily occurs due to the movement of dissolved metals; suspended particulates are less prone to migration due to the filtering action of subsurface aquifers. Thus, the analysis in this section concerning inorganic analytes only addresses the filtered sampling data for examining potential metals contamination.

Most of the metals detected in downgradient filtered groundwater samples were below the maximum detected in the local background well. A few of the detections for aluminum, arsenic, calcium, chromium, copper, lead, magnesium, manganese, potassium, sodium, vanadium, and zinc were in concentrations above the local background level. Many of these metals were not consistently detected in different rounds of sampling. The highest detections for magnesium, manganese, potassium, sodium and zinc were only slightly above local background levels, and probably indicate natural concentrations of these metals. The highest and most frequent detections for aluminum, arsenic, calcium, chromium, copper, and vanadium were in samples from the OHM-P11-33 well, which was sampled a total of four times by OHM and E & E. With the exception of arsenic, the metals found in the July 1992 OHM round were always the highest concentrations found in the OHM-P11-33 well out of the four rounds. Concentrations of aluminum, calcium, chromium, copper, and vanadium drop to much lower levels or were not detected in the remaining three rounds. The highest concentration of lead found in filtered groundwater was in the July 1992 round at OHM-P11-32 at 3.74  $\mu$ g/g, but no lead was detected in the three other rounds at this well. Of the metals found at the site in filtered groundwater samples, the only metal found consistently in all rounds in any single well above background levels was arsenic in the OHM-P11-33 well which was found ranging from 2.6  $\mu$ g/L to 8.21  $\mu$ g/L.

The only volatile organic compounds positively identified in sampling at the site was toluene, which was found in two of four rounds of sampling in the OHM-P11-33 well (see Table 4-3). Toluene was detected at 34  $\mu$ g/L in the July 1992 OHM round, and at 6.6  $\mu$ g/L in the November 1992 OHM round, but not in either of the 1993 E & E sampling rounds at this well. This was the only detection at the site that might indicate some form of solvent disposal, but the inconsistent detection of toluene does not confirm such a hypothesis. Further, the OHM-P11-33 well is located in an area that is upgradient of the area west of Building T405 along the fence that was allegedly used as a chemical disposal area. In addition, toluene was not detected in the E3-P11-M01 well, which is located further downgradient of the OHM-P11-33 well.

The only semi-volatile organic compound positively identified in groundwater sampling at the site was bis(2-ethylhexyl) phthalate, which was only found in EHA3 well in the October 1992 OHM round (7.3  $\mu$ g/L) and the November 1993 E & E round at 5.60  $\mu$ g/L (see Table 4-3). Bis(2-ethylhexyl)phthalate is a common plasticizer and it is possible that this detection could be a field sampling artifact.

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			Table 4-3		
	DETECTIONS I	N GROUNÓW	ATER ABOVE BAC	CKGROUND (μg/L)	•
Compound	Frequency Detected ¹	Max Concen- tration	Site ID	Max. in Local Background ²	Frequency Above Backgroun
Aluminum	3/23	1,300	OHM-P11-33	<28.9	2/23
Arsenic	8/23	8.21	OHM-P11-33	1.63	5/23
Calcium	23/23	69,000	OHM-P11-33	24,900	3/23
Chromium	3/23	23.5	OHM-P11-33	<10.0	1/23
Copper	7/23	21	OHM-P11-33	1.57	6/23
Lead	6/23	3.74	OHM-P11-32	< 5.0	6/23
Magnesium	23/23	4,240	E3-P13-M01	2,180	1/23
Manganese	15/23	271	E3-P13-M02	172	2/23
Potassium	21/23	4980	E3-P13-M02	3,800	5/23
Sodium	19/23	43,900	E3-P13-M02	43,700	1/23
Vanadium	3/23	42.4	OHM-P11-33	<10.0	3/23
Zinc	8/23	22.9	E3-P13-M04	<21.6	2/23
Bis (2- ethylhexyl) phthalate	2/19	7.3	ЕНА3	ND	2/19
Toluene	2/19	34	OHM-P11-33	ND	2/19
β-ВНС	1/25	0.033	E3-P13-M04	ND	1/25
Δ-ВНС	3/25	0.058	E3-P13-M02	ND	3/25
α- Chlordane	1/25	0.261	OHM-P11-33	ND	1/25
DDT	1/25	0.07	OHM-P11-33	ND	1/25
α- Endosulfan	1/25	0.028	E3-P13-M04	ND	1/25
β- Endosulfan	1/25	0.022	OHM-P11-33	ND	1/25
Heptachlor epoxide	1/25	0.026	OHM-P11-33	ND	1/25
Endrin	1/25	0.043	OHM-P11-33	ND	1/25
TPHC	3/15	535	E3-P13-M01	332	1/15

For filtered metals: 1 round at ATEC MW1/MW2, 2 rounds at E3-P11-M01, E3-P13-M01/M02/M04, OHM-P11-34, 3 Rounds at EHA3, 4 Rounds at OHM-P11-32/33. For target compound list VOAs and BNAs same as filtered metals except only one round at E3-P11-M01, E3-P13-M01/M02/M04. For target compound list pesticides same as filtered metals except two rounds at ATEC MW1/MW2. For TPHC, 1 round at EHA3, OHM-P11-32/33, 2 rounds at ATEC MW1/MW2, E3-P11-M01, E3-P13-M01/M02/M04.

Source: Ecology and Environment, Inc., 1994

² Local background well is E3-P13-M03.

Note: Metals are from filtered samples only, and were compared to filtered samples of local background well.

^{*} of inorganic analytes in filtered samples; of organic analytes in unfiltered samples

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Several pesticides were detected infrequently in groundwater sampling at the site.  $\alpha$ -chlordane (0.261  $\mu$ g/L), and trace levels of DDT (0.07  $\mu$ g/L),  $\beta$ -Endosulfan (0.022), heptachlor epoxide (0.026  $\mu$ g/L), and endrin (0.043) were found only in the OHM-P11-33 well in only one of four sampling rounds. Trace levels of  $\beta$ -BHC at 0.033  $\mu$ g/L, and  $\alpha$ -endosulfan were only found in one of two rounds in the E3-P13-M02 well. Trace levels of  $\Delta$ -BHC were found in one of two rounds at wells E3-P13-M01, E3-P13-M02, and E3-P13-M04 up to a maximum of 0.058  $\mu$ g/L (see Tables 4-3 and 4-9). Given the infrequency of detection and low levels detected, it is likely that these detections are residuals to the general pest management practices in the past at the Annex, rather than due to any spill or disposal of pesticides at the site.

TPHC was found only in groundwater samples from the August 1993 E & E round at wells E3-P11-M01, E3-P13-M01, and E3-P13-M02. Of these detections only the TPHC found at E3-P13-M01 (535  $\mu$ g/L) exceeded the TPHC found in the background well. The slightly elevated level at the E3-P13-M01 well could be related to the proximity of this well to the parking area, the road entering the site from White Pond Road, and White Pond Road itself. This pattern of detections does not indicate any significant TPHC groundwater contamination, but rather some low-level presence of TPHC probably related to nearby road runoff, or small leaks or spills from nearby parking areas. Further, the pattern of detections does not suggest a plume of TPHC, or residuals of large-scale infiltration of petroleum from USTs, ASTs, the gasoline station at Building T410, or fire training by the MFFA.

## 4.2.6 Surface Water and Sediment Sampling

As described in Section 3, surface drainage from the site is primarily in a southeastern direction from the site area toward the small tributary to Honey Brook, and eight samples were collected to characterize this pathway. In addition, groundwater drainage from parts of the site becomes surface water in the area of a seep located north of White Pond Road, and one sample was collected to characterize surface water/sediment quality at this point. Surface water and sediment samples were collected from the following locations: the wetlands west of Building T405 (E3-P11-D01); the tributary to Honey Brook just upstream of the small bridge on the road from the site to Site P26 (E3-P11-D02); in the drainages from the central and eastern portion of the site (E3-P13-D01/D02/D03); further downstream on the tributary to Honey Brook (E3-P13-D04/D05); in Honey Brook at Puffer Road (E3-P11-D03); and from the stream just below the groundwater seep (E3-P11-D04). Accordingly, the discussion in this section is conducted in two parts relating to the drainage to Honey Brook and the drainage via the groundwater seep. Surface water/sediment sampling points are identified on the Plate at the end of Volume I, and the six closest to the site are on the Plate at the end of this volume.

Analysis of the sediment samples indicated elevated concentrations of metals above local sediment background levels. It is important to note, however, that only two local background sediment samples were collected at the Annex, and thus the background sediment levels for inorganic analytes are poorly established and may underestimate or overestimate the true range of sediment background levels for the Annex. The two background sediment samples were collected in hard rock streams that had sediments with relatively low TOC

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content (maximum of  $14,200 \mu g/g$ , 1.4 percent), especially in comparison to samples collected in wetland areas at the Annex that can have TOC content up to 50 percent. Three of the sediment samples for investigation of this site (E3-P11-D01, E3-P11-D04, and E3-P13-D01) had TOC contents greater than 10 percent. The remainder of the sediment samples had TOC less than 10 percent. Organic-rich sediments will tend to have consistently higher natural metals concentrations due to the greater sorbing potential of sediments with large amounts of organic carbon. Thus, the local background stream sediment samples are most likely to underestimate background levels of metals in organic-rich sediments. Inorganics found in sediments were compared to the background stream sediment levels, but were also compared to the metals concentrations found in the sediments in the background pond (Minister's Pond), when the TOC content was greater than ten percent. The background pond sediments had TOC contents ranging from 34 to 58 percent. As a further means of comparison, concentrations of metals found at levels more than twice their respective background comparison levels are also noted in the discussion below.

## 4.2.6.1 Drainage to Honey Brook

### **Surface Water**

In the surface water sample from the wetlands west of Building T405 (at E3-P11-D01), several metals including aluminum (3,500  $\mu$ g/L), barium (65.3  $\mu$ g/L), manganese (530  $\mu$ g/L), and zinc (74.2  $\mu$ g/L) were found in concentrations more than twice background stream levels. Copper, lead and vanadium were also found in concentrations above background. These samples were collected in a low-flow area of organic-rich sediments. Given that organic-rich sediments often have naturally higher levels of metals, and that some sediment is often captured during surface water sampling of low-flow streams (particularly in wetland areas) these detections in the surface water sample could be influenced by suspended sediment in the surface water sample. Acetone (12.0  $\mu$ g/L) was also found in this sample, but not in the duplicate sample. Given that the volatilization potential of acetone is high and that acetone was not found elsewhere at the site, the likely source of this detection is laboratory contamination.

In the surface water sample (at E3-P11-D02) taken in the tributary to Honey Brook at the bridge to P26 several metals were found at levels slightly above background: barium (14.2  $\mu$ g/L), calcium (11,200  $\mu$ g/L), and magnesium (1,960  $\mu$ g/L). Zinc (at 35.0  $\mu$ g/L) was found in a concentration more than twice background. All other metals were found within the background range. No organic compounds were detected in this sample.

In surface water samples collected from the drainage from the central and eastern part of the site (at E3-P13-D01 and E3-P13-D03), several metals were found above background and DDT and its degradation products DDD and DDE were also detected. In the sample collected just downstream of the small on-site wetland (at E3-P13-D03), aluminum (746  $\mu$ g/L), barium (11.8  $\mu$ g/L), and lead (12.3  $\mu$ g/L) were found at levels slightly above background, while zinc (at 181  $\mu$ g/L) was elevated more than twice above stream background levels. DDT (0.263  $\mu$ g/L), DDD (0.018  $\mu$ g/L) and DDE (0.055  $\mu$ g/L) were also detected in this sample. In the sample collected further downstream in the drainage from the central

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portion of the site (at E3-P13-D01), several metals were slightly elevated above background including aluminum (501  $\mu$ g/L), calcium (11,000  $\mu$ g/L), iron (5,100  $\mu$ g/L), lead (11.1  $\mu$ g/L), and magnesium (2,610  $\mu$ g/L). Several other metals were found at more than twice background levels including arsenic (4.60  $\mu$ g/L), barium (24.6  $\mu$ g/L), potassium (6,010  $\mu$ g/L), and zinc (70.8  $\mu$ g/L). Most of the metal concentrations found in the sample at E3-P13-D01 were higher than those found in the E3-P13-D03 sample upstream at the site itself, with the exception of aluminum, lead, and zinc, which were higher in the upstream sample. DDT was not detected in the sample at E3-P13-D01, but its degradation products DDD (0.016  $\mu$ g/L) and DDE (0.019  $\mu$ g/L) were found at levels slightly lower than in the upstream sample at E3-P13-D03. E3-P13-D04 showed no evidence of organics of TPHC, but the metals data was disqualified by QA/QC review, with the exception of a non-detect value for mercury.

In a surface water sample taken further downstream in the tributary to Honey Brook (at E3-P13-D05), most of the metal concentrations were found at levels within the background stream range. The only metal found above background was zinc (23.9  $\mu$ g/L). No pesticides or other organic compounds were detected in two samples collected (at E3-P13-D04 and D05) on the tributary to Honey Brook at this point.

The furthest downstream sample for this site in the Honey Brook drainage (at E3-P11-D03) was collected approximately 1,600 feet downstream from the site on Honey Brook. This sample location was approximately 30 feet east of Puffer Pond Road at a point that is downstream of Sites P4, P11, P13 and P26. Manganese (33.3  $\mu$ g/L) was found in a concentration slightly above background, while arsenic (7.01  $\mu$ g/L) and zinc (30.7  $\mu$ g/L) were detected in the surface water sample at concentrations more than twice the background levels. No pesticides or other organic compounds were detected in the sample at this location. These results for surface water are summarized in Table 4-4.

## **Sediments**

In the sediment sample from the wetlands west of Building T405 (at E3-P11-D01), aluminum, arsenic, beryllium, copper, lead, and selenium were found above the stream sediment background levels. However, this sediment sample had a relatively high TOC content (143,000  $\mu$ g/L), and was thus compared to sediment levels from the background pond. Aluminum, beryllium, and selenium were the only metals found above background pond levels. Of these three metals, only selenium was found in a concentration (0.572  $\mu$ g/g) more than twice the background pond level. The DDT degradation products DDD (0.010  $\mu$ g/g) and DDE (0.022  $\mu$ g/g) were also found in this sample, as well as TPHC (26.0  $\mu$ g/g). The DDD and DDE detections were within the range found in background pond sediments.

The sediment sample collected from the tributary to Honey Brook at the bridge to Site P26 (at E3-P11-D02) had the following metals in concentrations above the background stream sediment range for metals but less than twice the highest detection in background: aluminum, arsenic, barium, beryllium, copper, nickel, and zinc. Calcium  $(1,610 \mu g/g)$ , lead  $(31.0 \mu g/g)$ , and selenium  $(0.724 \mu g/g)$  were found in concentrations more than twice

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		Table 4-4			
DETEC	CTIONS IN SURFACE WATER I BACK	N THE DRAINAGE GROUND (μg/L)	TO HONEY	BROOK	ABOVE
	Movimum	T	Man	· T	Т.

Compound	Frequency Detected ¹	Maximum Concen- tration ²	Site ID	Max. in Local Background	Frequency Above Background
Aluminum	5/5	3,500	E3-P11-D01	400	4/5
Arsenic	5/5	4.60	E3-P13-D01	3.15	1/5
Barium	5/5	65.3	E3-P11-D01	10.4	4/5
Beryllium	1/5	0.217	E3-P11-D01	0.18	1/5
Calcium	5/5	11,200	E3-P11-D02	8,520	1/5
Iron	5/5	5,100	E3-P13-D01	4,810	1/5
Lead	3/5	17.3	E3-P11-D01	10.3	3/5
Magnesium	5/5	2,610	E3-P13-D01	1,890	1/5
Manganese	5/5	530	E3-P11-D01	156	1/5
Potassium	1/5	6,010	E3-P13-D01	2,060	1/5
Vanadium	3/5	7.87	E3-P11-D01	4.72	1/5
Zinc	5/5	181	E3-P13-D03	13.3	5/5
Acetone	1/5	12.0 ³	E3-P11-D01		
DDD	2/6	0.018	E3-P13-D03		
DDE	2/6	0.055	E3-P13-D03		
DDT	1/6	0.263	E3-P13-D03		

All samples are E & E samples as follows: E3-P11-D01/D02, E3-P13-D01/D03/D04/D05; E3-P13-D04 only analyzed for pesticides. Results from E3-P11-D03 are not included due to the distance from site, presence of other sites in proximity to sample point, and proximity to Puffer Road.

² Results for E3-P11-D01 are average of sample and duplicate.

³ ND in duplicate.

Source: Ecology and Environment, Inc., 1994

background levels. DDT (0.038  $\mu$ g/g), DDD (0.100  $\mu$ g/g), and DDE (0.079  $\mu$ g/g) were also detected in this sample.

In the three sediment samples collected from the drainages from the central and eastern parts of the site (at E3-P13-D01/D02/D03), metals, pesticides, and TPHC were found above background. In the sample collected from the drainage from the on-site wetland (at E3-P13-D03), numerous metals were found above background, but only arsenic (4.71  $\mu$ g/g), cobalt (7.07  $\mu$ g/g), copper (29.6  $\mu$ g/g), iron (26,000  $\mu$ g/g), lead (23.0  $\mu$ g/g), nickel (12.0  $\mu$ g/g) and zinc (370  $\mu$ g/g) were found in concentrations more than twice the stream sediment levels. DDT (0.230  $\mu$ g/g), DDD (0.170  $\mu$ g/g), and DDE (0.120  $\mu$ g/g) were found in this sample as well as TPHC (263  $\mu$ g/g). In the sample collected from the drainage east of Building T408 (at E3-P13-D02), several metals were also elevated above background, but none were more than twice the stream sediment levels. DDT (0.012  $\mu$ g/g), DDD (0.0087  $\mu$ g/g), and DDE (0.022  $\mu$ g/g) were detected in this sample, but TPHC was not found. The highest concentrations of most compounds among these three samples were found in the

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sample collected just below the confluence of two drainages from the central and eastern parts of the site (at E3-P13-D01). This sample was collected from organic rich sediments (TOC content of 628,000  $\mu$ g/g). Almost all of the metals detected in this sample were above the stream sediment background levels and most of the metals including arsenic, barium, beryllium, calcium, lead, magnesium, manganese, nickel, selenium, cadmium, and zinc were elevated above the range for metals in background pond sediments. However, only calcium (19,400  $\mu$ g/g), selenium (1.94  $\mu$ g/g), and zinc (277  $\mu$ g/g) were found in concentrations more than twice the background pond levels. DDT (0.150  $\mu$ g/g) was found in the sample at E3-P13-D01 but at a lower level than in the sediment sample collected closer to the site (at E3-P13-D03). The concentrations of DDD (0.760  $\mu$ g/g) and DDE (0.540  $\mu$ g/g), however, were much higher in the downstream sample at E3-P13-D01 than in those at the site itself. TPHC was detected in the sample at E3-P13-D01 at a level slightly higher (295  $\mu$ g/g) than further upstream.

In the sediment sample collected further downstream in the tributary to Honey Brook, the concentrations of metals in general were much lower than in the samples taken in the drainages from the central and eastern parts of the site. The one notable exception was arsenic, which was found in the E3-P13-D04 at 37.0 µg/g; this was the highest arsenic detection in sediments at the site. In the sample at E3-P13-D04, beryllium (0.365  $\mu$ g/g), calcium  $(1,170 \mu g/g)$ , lead  $(23.0 \mu g/g)$ , nickel  $(7.89 \mu g/g)$ , and selenium  $(0.537 \mu g/g)$  were also found above background, but at lower levels than in the sample further upstream at the confluence of the drainages from the central and eastern parts of the site (E3-P13-D01). Of these six metals, only nickel was found in a concentration less than twice background levels. DDT (0.019  $\mu$ g/g), DDE (0.037  $\mu$ g/g), and DDD (0.020  $\mu$ g/g) were also detected. At the sample at E3-P13-D05 which is the furthest downstream sample collected in the tributary to Honey Brook, the only metals detected above background were calcium and lead, which were found in concentrations only slightly above stream sediment background levels. DDT was not detected in this sample, but DDE (0.022  $\mu$ g/g) and DDD (0.025  $\mu$ g/g) were found. Several PAHs, including benzo(b)fluoranthene (0.082  $\mu$ g/g), fluoranthene (0.120  $\mu$ g/g), and pyrene  $(0.068 \mu g/g)$  were also found in this sample, which was collected just adjacent to the bridge on the road from Puffer Road to Site P26. The PAHs, since they were not found further upstream, are probably related to the road crossing at this point.

In the sediment sample collected on Honey Brook just downstream of Puffer Road (E3-P13-D03), the sampling results indicated several metals including arsenic, cobalt, lead, magnesium, manganese, and nickel were found above background levels, but only the concentrations of arsenic (4.84  $\mu$ g/g), magnesium (88,700  $\mu$ g/g), and manganese (148  $\mu$ g/g) were more than twice background levels. Numerous PAH compounds were also found including anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene all in a range between 0.150  $\mu$ g/g and 1.40  $\mu$ g/g. Given the proximity of Puffer Road, and that most of these compounds were not detected further upstream in Honey Brook or in the tributary to Honey Brook, the likely source of these PAHs is Puffer Road itself. Trace levels of several pesticides, including DDT (0.01  $\mu$ g/g), DDE (0.015  $\mu$ g/g) and  $\alpha$ -BHC (0.001  $\mu$ g/g) were also detected in this sample. Table 4-5 summarizes results for sediments in the drainage to Honey Brook.

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Compound	Frequency Detected ¹	Max Concen- tration ²	Site ID	Max. in Stream/Pond Background ³	Frequency Above Background
Aluminum	7/7	8,700 6,300	E3-P11-D01 E3-P11-D02	5740 5020	1/2 1/5
Arsenic	7/7	10.5 37.0	E3-P13-D01 E3-P13-D04	9.56 2.03	1/2 4/5
Barium	7/7	59.2 25.7	E3-P13-D01 E3-P11-D02	55.3 23.9	1/2 1/5
Beryllium	7/7	0.632 0.365	E3-P13-D01 E3-P13-D04	<0.5 0.18	2/2 3/5
Cadmium	1/7	1.43	E3-P13-D03	< 0.5	1/5
Calcium	6/7	19,800 1,610	E3-P13-D01 E3-P11-D02	4,550 562	1/2 4/5
Chromium	7/7	10.5 15.2	E3-P13-D01 E3-P13-D02	12.8 9.66	0/2 2/5
Cobalt	7/7	9.9 7.07	E3-P13-D01 E3-P13-D03	11.4 3.74	0/2 2/5
Copper	7/7	21.6 29.6	E3-P13-D01 E3-P13-D03	10.9 6.33	1/2 2/5
Iron	7/7	76,500 26,000	E3-P13-D01 E3-P13-D03	16,300 7590	1/2 2/5
Lead	7/7	71.0 31.0	E3-P13-D01 E3-P13-D02	49.4 4.48	1/2 5/5
Magnesium	7/7	2,165 1,990	E3-P13-D01 E3-P13-D02	1,480 2140	1/2 0/5
Manganese	7/7	71.6 84.3	E3-P13-D01 E3-P13-D01	74.1 70.5	0/2 2/5
Nickel	7/7	26.5 12.0	E3-P13-D01 E3-P13-D03	23.2 5.12	1/2 4/5
Selenium	4/7	2.30 0.724	E3-P13-D01 E3-P11-D02	<0.2 0.2	2/2 2/5
Vanadium	7/7	26.9 13.0	E3-P13-D01 E3-P13-D02	21.8 17	1/2 0/5
Zinc	7/7	273 370	E3-P13-D01 E3-P13-D03	55.3 20.8	1/2 2/5
Benzo(b) fluoranthene	1/7	0.082	E3-P13-D05		
Fluoranthene	1/7	0.120	E3-P13-D05		
Pyrene	1/7	0.068	E3-P13-D05		
DDD	7/7	0.725 0.170	E3-P13-D01 E3-P13-D03	0.39 ND	2/2 5/5

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Table 4-5	
DETECTIONS IN SEDIMENTS IN THE DRAINAGE TO HONEY BROOK ABOVE BACKGROUND $(\mu g/g)$	

		3.10110	TOOTIE (FB/B)		
Compound	Frequency Detected ¹	Max Concen- tration ²	Site ID	Max. in Stream/Pond Background ³	Frequency Above Background
DDE	7/7	0.510 0.120	E3-P13-D01 E3-P13-D03	0.074 ND	2/2 5/5
DDT	5/7	0.130 0.230	E3-P13-D01 E3-P13-D03	<0.01 ND	1/2 4/5
TPHC	3/7	175 263	E3-P13-D01 E3-P13-D03	16.6	2/2 1/5

All samples are E & E samples as follows: E3-P11-D01/D02, E3-P13-D01/D02/D03/D04/D05; Results from E3-P11-D03 are not included due to the distance from site, presence of other sites in proximity to sample point, and proximity to Puffer Road. All results for E3-P13-D01 are average of sample and duplicate sample.

³ The top background level is for sediments from the background pond; the bottom background level is for sediments from the background streams.

Source: Ecology and Environment, Inc., 1994.

### 4.2.6.2 Drainage via the Groundwater Seep

#### Surface Water

The detailed contours of groundwater elevations incorporating data from Sites A7, A8, A9, P11, P13, and P57 clearly show that the perennial stream north of White Pond Road and its associated wetlands are groundwater discharge points from both east and west. Because of the configuration of the water table it is clear that the spring and its adjoining wetland captures groundwater from at least part of Site A8, part of Sites P11 and P13, and all of Site P57. The spring itself, depending on its average rate of flow, may only intercept flow from northern part of Site P11/P13 and the area north of White Pond Road. If this area is approximately 300 feet wide and 800 feet long, and infiltration is equivalent to 22 inches per year, the average groundwater discharge would be approximately 6 gallons per minute or 9,000 gallons per day. This is in accord with field observations.

Reconnaissance of the area around the groundwater seep in April 1994 revealed the presence of a hillside debris dump. Much of the debris appeared to be decades old, and included various pieces of metal and glassware. Some of the detections in the surface water/sediment samples at the seep may be related to this debris.

² Samples with TOC content greater than 10% (E3-P11-D01 and E3-P13-D01) were compared to background pond levels; the top line for each compound refers to the detections in these two organic-rich sediment samples, while the bottom line refers to the detections for the remaining sediment samples; cadmium and PAHs were only found in one sample each and were compared to stream sediment background levels.

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Because of this low flow and the highly organic and fine-grained nature of the sediments at the spring, there is no natural area of flowing water with a clean sandy bottom where sample containers can be submerged without the sample becoming turbid with suspended solids. The relatively high levels of metals in the sample collected on 1 December 1993 (at E3-P11-D04) is confirmed to be the result of suspended solids by comparison with a sample from the same location taken at a later date (26 April 1994). The April 1994 surface water sample was taken from a small pond that was excavated 24 hours prior to sampling in order to obtain a non-turbid sample (total suspended solids (TSS) of 5  $\mu$ g/g). The results of data of the resampling on 26 April 1994, show that the sample contained much lower metals concentrations than in the turbid December 1993 surface water sample. Analysis of the April 1994 sample indicated no detectable mercury, lead, arsenic, antimony, chromium, cobalt, nickel, or thallium. The sample did contain low levels of beryllium, calcium, copper, magnesium, and potassium, slightly above background levels. Silver (2.31 µg/L) and zinc  $(49.8 \mu g/L)$  were found in concentrations more than twice background levels. On this basis, the April 1994 sample was selected as the more representative of the surface water conditions at the site.

#### Sediment

In the sediment sample taken in December 1993 at the groundwater seep (at E3-P11-D04), arsenic, barium, beryllium, calcium, cobalt, lead, nickel, selenium, silver, and zinc were found above stream sediment levels. Although TOC was not analyzed for in the December 1993 sediment sample, based on the TOC content  $(107,000 \ \mu g/L)$  in the April, 1994 sample collected at the same location, it has been assumed that the December 1993 sample contained a similar amount of TOC content. Thus, the metal concentrations in the December 1993 sample were also compared to background pond levels. The concentrations of arsenic, beryllium, calcium, nickel, selenium, and silver were found to be above background pond sediment levels, but only calcium  $(10,500 \ \mu g/g)$ , selenium  $(3.17 \ \mu g/g)$ , and silver  $(1.89 \ \mu g/g)$  were found in concentrations more than twice background levels. TPHC was also detected at  $106 \ \mu g/g$ , in the December 1993 sample.

The groundwater seep was resampled in April 1994 and the sediment sample was analyzed for metals, TOC, and TPHC. In general, the metal concentrations were lower than in the earlier sampling, but several metals including antimony, beryllium, lead, manganese, selenium, and zinc were found above stream sediment background levels. As noted above, these sediments are relatively organic-rich (TOC content 107,000  $\mu$ g/g), thus making a comparison to background pond sediment appropriate. Only antimony (1.01  $\mu$ g/g), beryllium (0.201  $\mu$ g/g), and selenium (1.08  $\mu$ g/g) were found above the metals range in background pond sediments, but only antimony (1.01  $\mu$ g/g) and selenium (1.08  $\mu$ g/g) were found in concentrations more than twice background pond levels. TPHC was not detected in the April 1994 sediment sample.

## 4.3 CONCLUSIONS

In surface soils, the key contaminants of concern are metals, pesticides, PAHs and PCBs, but only in limited areas. The pesticide detections in soil are probably related to

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general pest management practices rather than the pesticide research at Building T405, particularly due to the fact that soil samples to date have only been collected in areas upgradient of Building T405. In the former area of fire training by the MFFA in the parking lot, there appears to be a limited area of metals, PAH, and pesticide contamination near the

	WNSTREAM OF T	Table 4-6 URFACE WATER AND THE GROUNDWATE BACKGROUND ¹	
Media	Compound	Concentration	Max. in Background ²
	Beryllium	0.268	< 5.0
	Calcium	10,500	8,520
	Copper	4.03	<10.0
SW (μg/L)	Magnesium	2,310	1,890
(Mg/L)	Potassium	2,120	2,060
	Silver	2.31	ND
	Zinc	49.8	13.3
	Antimony	0.750	< 0.5
	Beryllium	0.241	<0.5
Sed	Calcium	6,700	4550
(μg/g)	Selenium	2.12	< 0.2
	Silver	1.05	0.879
	TPHC	63	

At sample location E3-P11-D04; surface water detections from 4/26/94 sample only due to high turbidity in 12/2/93 surface water sample; sediment detections are average of concentrations found in 12/2/93 and 4/26/94 samples.

Source: Ecology and Environment, Inc., 1994

former location of the burn pan. The metals and PAHs are likely to be related to former flammable liquid and car fire training by the MFFA. At the former location of the 500 gallon UST northeast of Building T406, the soil contained metals, pesticides and low levels of PCBs. The metals may be result of degradation of galvanized steel in the AST. The PCBs may be related to a nearby transformer located immediately north of Building T406 or a spill of waste oil. At the former location of the ASTs east of Building T410, several metals were found above background, as well as one low level detection of PCBs. The metals may be related to the former ASTs, and the source of the PCBs could be a small spill of waste oil.

In subsurface soil, the only contaminant found consistently was TPHC found in excavations of the former USTs at the site. Residual levels of TPHC after removal and remedial actions were completed at the USTs ranged from non-detect to 63  $\mu$ g/g for the

² Surface water background levels are from local background streams. The E3-P11-D04 sediment sample had a TOC content greater than 10 percent and thus metals concentrations in sediment were compared to background pond levels.

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Buildings T405, T406, T407, T408, and T409 USTs. The subsurface soil at the former location of the Building T410 UST had slightly higher TPHC levels ranging from 11  $\mu$ g/g to 187  $\mu$ g/g, which may also be related to the gasoline station operations at Building T410. No contaminants of concern were identified in OHM boring samples from the three OHM wells near Building T405. No pesticides were found in the two ATEC borings taken near Building T405. Cadmium (7.72  $\mu$ g/g to 13.0  $\mu$ g/g) was the only detection in the soil from the two test pits excavated in the area west of Building T405 likely to indicate potential contamination.

In groundwater sampling, no contaminant plumes were identified at the site. Several localized potential concerns were raised by sampling results. As discussed above, for inorganic analytes, discussion of potential contamination has focused only on filtered sampling results, due to the difficulty of assessing unfiltered samples which inevitably contain suspended solids. Several metals, including aluminum, arsenic, calcium, copper, and vanadium were consistently detected in multiple (filtered) sampling rounds from the OHM-P11-33 well above local background levels. This well is located just east of Building T405. Pesticides were also found in this well at relatively low levels (all less than 1  $\mu$ g/L), but only in one of four sampling rounds. Toluene was also found in two of four sampling rounds up to 34 µg/L. The source of the metals is unknown. The pesticides could potentially be related to pesticide research conducted at Building T405 but may also be related to infiltration of pesticides from the surface due to general pest control practices. The toluene could be related to solvents used in research at Building T405, but the infrequent and low-level nature of detections does not indicate a large-scale spill. These detections appear to be limited to this well, as metals were not elevated above background and no volatile organics or pesticides were found in samples collected from the E3-P11-M01 well, which is located downgradient of the OHM-P11-33 well. Low-levels of several other pesticides were infrequently detected in several other wells (E3-P13-M01, M02 and M04) in areas upgradient of Building T405, and the source of these detections is probably general pest control practices. Bis(2ethylhexyl)phthalate, a common plasticizer, was detected in two of three rounds of sampling at the EHA3 well (up to 7.3  $\mu$ g/L), and this detection could be a field sampling artifact. TPHC was detected infrequently in several wells at the site up to 535  $\mu$ g/L. The infrequency and relatively low levels of detection does not indicate extensive TPHC contamination at the site, but may indicate some limited infiltration of petroleum or gasoline from activities at the site.

As described above, surface water and sediment samples were collected in the drainages from the site leading to Honey Brook, and also at the seep which receives groundwater drainage from a small portion of the site. Also as noted above, there were only two background surface water and sediment samples, and thus the background levels may underrepresent the actual natural levels of metals. Thus, the discussion above has noted all detections above background but focused on those more than twice above background. In the drainages toward Honey Brook, various metals were found in surface water samples, but most were either within or only slightly above the background levels. Several metals, including zinc were more than twice background levels in surface water in wetlands west of Building T405, but these detections may be the result of organic-rich sediment captured in the sediment sample. Zinc was the only compound found in concentrations more than twice the background concentration in surface water further downstream of the wetlands. In the

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drainages from the central part of the site toward Honey Brook, there appears to be elevated levels of zinc and DDT and its degradation products in surface water draining from the on-site wetland. Zinc was also found at levels more than twice background in two surface water samples downstream in the drainage toward Honey Brook. DDT was not found in surface water further downstream, but its degradation products DDD and DDE were found in the downstream sample in the drainage from the on-site wetland. DDD and DDE were not found in the further downstream samples collected in the tributary to Honey Brook. Overall, it appears that zinc and the pesticide DDT and/or its degradation products may be migrating in surface water off-site, but their concentrations decline rapidly as distance increases from the site, and decline below detection limits prior to the drainage entering Honey Brook.

In sediments in the drainage from the site toward Honey Brook, the key concerns raised by sampling results is the presence of metals, pesticides, and TPHC in sediments in drainage from the central part of the site and the on-site wetland. While metals were often detected above background levels in sediments in this drainage, many of the detections were infrequent or were only slightly above background levels. In the wetlands west of Building T405, the only metal found more than twice the background concentration was selenium, and the only metals found downstream of these wetlands in the tributary to Honey Brook at levels more than twice the background concentration were calcium, lead, and selenium. In the drainage from the eastern part of the site, no metals were elevated more than twice above background. In the drainage from the central portion of the site and the on-site wetland, arsenic, cobalt, copper, iron, lead, nickel, and zinc were found in concentrations twice background. Many of these metals were found at higher concentrations in organic-rich sediments at a downstream sample at the confluence of several drainages from the site. The pattern of detections suggest some limited migration of metals in the central drainage from the on-site wetland, with metals collecting in the organic-rich sediments further downstream. In sediment samples collected even further downstream in the tributary to Honey Brook, metals concentrations were still above background but were found in lower levels than further upstream close to the site. One exception is the detection of arsenic at E3-P13-D04 of 37.0  $\mu g/g$ , which was the highest detection of arsenic in samples related to this site. The pesticide DDT and its degradation products were found in most of the sediment samples in a similar pattern to the metals, with higher concentrations in samples collected closer to the site declining to trace levels at the furthest downstream samples in the tributary to Honey Brook. TPHC was also detected in three of the sediment samples taken in close proximity to the site, with the highest detection in the sample from below the on-site wetland (E3-P13-D03). PAHs were only found in one sample collected adjacent to a road crossing the tributary to Honey Brook. Overall, the primary finding indicated by sampling results is a limited presence of metals, pesticides, and TPHC in some of the sediments in the drainage from the central portion of the site, with a declining impact on the tributary to Honey Brook as distance from the site increases.

Sampling of the groundwater seep northeast of the site indicated the presence of several metals at levels more than twice background levels in surface waters and sediments as well as TPHC. However, immediately upgradient of the sample point is a small decades-old metal debris dump, and the source of these detections is likely to be localized, rather than related to the P11/P13 site. This hypothesis is supported by groundwater sampling at the site,

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which did not identify particularly elevated metals in filtered sampling of the two wells located upgradient of the seep (EHA3 and E3-P13-M01). The TPHC detection could be related to the site, given the infrequent detection of TPHC in the E3-P13-M01 well, but could also be related to the debris dump.

In relation to the potential sources identified in Section 4.1, the research activities conducted at the site do not appear to have been sources of significant contamination at the site. No explosives were detected which would identify residuals of any explosive testing that may have been conducted as part of ordnance research. While a few volatile organic compounds were detected in various media at the site, their detection levels and the infrequency of their detection do not confirm either dumping or large-scale spills of organic compounds generated during foamed plastics or organic synthesis research at Building T405. The research on pesticides at Building T405 may have contributed to some of the pesticide detections, but the pattern of pesticides found is more consistent with general pest management practices. The former USTs at the site have resulted in some very limited TPHC presence in soils in the immediate area of the USTs, but with the exception of the UST at Building T410, earlier remedial efforts appear to have removed all soil with TPHC greater than 100  $\mu$ g/g. The fire training activity by the MFFA in the parking area has apparently resulted in a localized area of metals and PAH contamination in the immediate area of the former burn pan. Some limited PCB soil contamination, possibly related to waste oil, is present near the former AST at Building T406 (which may instead be related to the transformer at Building T406) and near the former ASTs at T410. The combination of gas station operations and flame testing at Building T410, vehicle parking, and residual TPHC related to MFFA fire training or the removed USTs and ASTs seems to have resulted in the limited presence of TPHCs in groundwater, surface water, and sediments.

Date: 10/27/9	4		Table:	4-7		Page 1 of 1
File Type: CSO	3O 0RF	Ö	Chemical Summary Report For Subsurface Soils Site: P11	ort For Subsurface	Soils	Part 1 of 2
na indica min			Units:	nge		
	Site ID					
	Field Sample ID					
	Sample Date	08/03/93				
Test	Parameter Depth	0.0 ft.				
TOC	Total Organic Carbon	4560				
		The second secon				
			7			

Source: USAEC IRDMIS Level 3/E & E, 1994

Site ID	Date: 10/27/94			Table: 4-7	: 4-7		Page	1 of 1
Site: P13   Units: UGG	File Type: CSt	. 0	Ch	emical Summary Rep	oort For Subsurface S	Soils	Part	2 of 2
Site ID   E3-P13-M01   E3-P13-M02   E3-P13-M03     Field Sample ID   BX1301X1   BX1302X1   BX1303X1     Sample Date   08/02/93   08/03/93   08/03/93     Parameter   Depth   0.0 ft.   9.0 ft.   9.0 ft.     Total Organic Carbon   4310   5660   4330	Site Type: BO	RE		Site	e: P13 s: UGG			
Field Sample ID   BX1301X1   BX1302X1   BX1303X1     Sample Date		Site ID	E3-P13-M01	E3-P13-M02	E3-P13-M03	E3-P13-M04		
Sample Date	,	Field Sample ID	BX1301X1	BX1302X1	BX1303X1	BX1304X1		
Parameter   Depth   0.0 ft.   9.0 ft.   9.0 ft.     Total Organic Carbon   4310   5660   4330   615     Total Organic Carbon   4310   615     Total Organic Carbon		Sample Date	08/02/93	08/03/93	08/03/93	08/02/93		
Total Organic Carbon 4310 5660 4330	Test	Parameter Depth	0.0 ft.	9.0 ft.	9.0 ft.	0.0 ft.		
	TOC	Total Organic Carbon	4310	2660	4330	6130		
		•			•			
							76	
	(6)							

Source: USAEC IRDMIS Level 3/E & E, 1994

Date: 10/27/94	-		Table	Table: 4-8			Page 1 of 1
File Type: CGW	W		Chemical Summary Report For Groundwater	Leport For Groundwa	iter		
Site Type: WELL	IL		Sit Unit	Site: P11 Units: UGL			38
	Site ID	ATEC-1	ATEC-1	ATEC-1	ATEC-2	ATEC-2	ATEC-2
	Field Sample ID	MFP11A12	MXP11A11	MXP11A12	MFP11A22	MXP11A21	MXP11A22
	Sample Date	11/30/93	09/02/93	11/30/93	11/30/93	09/02/93	11/30/93
Test	Parameter.						
TAL METAL	Aluminum	39.1 B	14000 !	1 00061	16.1 BJ	17000 !	2740
	Antimony	4.86 BJ	< 5.00	< 5.00	8.04 B	< 5.00	< 5.00
	Arsenic	< 2.00	11.0 J!	13.3	< 2.00	4.00 J	1.14 J
	Barium	6.16 J	66.3	81.8 i	11.8	40.7	22.6
	Beryllium	< 5.00	0.755 JK!	0.299 J	< 5.00	0.999 JK!	< 5.00
	Cadmium	< 5.00	2.06 J!	< 5.00	1.88 Ji	< 5.00	< 5.00
	Calcium	3480	3910	4950	5070	3510	2080
	Chromium	< 10.0	25.1	23.4 !	< 10.0	29.5 !	4.86 J
	Cobalt	< 10.0	11.8	11.8	< 10.0	10.3	< 10.0
	Copper	< 10.0		24.8	< 10.0	23.7	3.37 J
	Iron	11.2 BJ	16000 K!	i 00061	< 25.0	16000 K!	2600 !
	Lead	< 5.00	5.90 !	7.78 !	< 5.00	1.88	1.12 BJ
	Magnesium	411 J	4480 !	4490 i		5430 !	1070
	Manganese	25.6	210	221 !	12.6 K	220 !	55.1
	Nickel	< 10.0	23.0	20.9	< 10.0	25.6 !	< 10.0
	Potassium	811 J	3860	4200	2240	6190	4490
	Sodium	6580 K	6270	7540 K	6160 K	7320	6950 K
	Vanadium	< 10.0	29.0	29.5	< 10.0	37.3	4.14 J
	Zinc	22.9 K!	47.9 B	394 i	11.3 BJ	51.3 B	264 !
TCL BNA	Bis(2-ethylhexyl)phthalate		< 10.0	< 11.0		< 10.0	< 10.0
TPHC	Total Petroleum Hydrocarbons	5	< 2000	< 2000		< 2000	< 2000

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only) J= Estimated value. L= Result bias low. K= Result bias high. R= Result rejected.

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

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Date: 10/27/94	4		Laple	Table: 4-8			rage 1 of
File Type: CGW	J.W.		Chemical Summary Report For Groundwater Site: P11	y Report For Groundwa Site: P11	ter		Part 2 of 4
one type. w			Unit	Units: UGL			
	Site ID	E3-P11-M01	E3-P11-M01	E3-P11-M01	E3-P11-M01	E3-P11-M01	E3-P11-M01
	Field Sample ID	MD1101F1	MD1101X1	MF1101X1	MFP11012	MX1101X1	MXP11012
	Sample Date	08/24/93	08/24/93	08/24/93	11/30/93	08/24/93	11/30/93
Test	Parameter .						
TAL METAL		14.8 BJ	37000 !	14.7 BJ	24.9 BJ	31000 !	8520
		2.46 BJ	< 5.00	4.11 BJ	7.30 B	2.36 Ji	< 5.00
	Arsenic	< 2.00	8.49 Ji	< 2.00	< 2.00	5.91 J	2.83
	Barium	8.52 J	177 !	8.79 J	11.0	164	54.7
	Beryllium	< 5.00	1.71 J	< 5.00	< 5.00	1.51 J	< 5.00
	Cadmium	< 5.00	4.14 Ji	< 5.00	< 5.00	2.66 Ji	< 5.00
	Calcium	6120	11500	6140	8460	10600	13200
	Chromium	5.34 J	i 8.79	< 10.0	< 10.0	61.0	15.8
	Cobalt	< 10.0	28.4	4.62 J	< 10.0	24.3	4.03 J
	Copper	< 10.0	48.3	< 10.0	< 10.0	42.4	14.3
	Iron	22.3 BJ	41000 !	26.9 B	12.0 BJ	34000 !	9120
	Lead	< 5.00	17.1	< 5.00	< 5.00	13.8	3.98 KJ!
	Magnesium	1060	12500 !	1090	268	100001	3480
	Manganese	212	621 !	212	58.2	556 !	156
	Nickel	< 10.0	1 9.07	< 10.0	< 10.0	52.5	17.1
	Potassium	3010	100001	3080	2210	i 0226	4310
	Sodium	3330	4700	3370	8920 K	4410	10100
	Vanadium	< 10.0	74.9 !	< 10.0	< 10.0	64.8	16.8
	Zinc	14.7 BJ	120 K!	17.9 BJ	12.1 BJ	99.6 K!	303
TCL BNA	Bis(2-ethylhexyl)phthalate						< 10.0
TPHC	Total Petroleum Hydrocarbons	S	< 2000			187 J	132 BJ
L							

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only) J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected.

File Type: CGW Site Type: WELL	, T		Chemical Summary F	Chemical Summary Report For Groundwater Site: P11	ater		Part 3 of 4
Site Type: WEI	T		Sir	fe: P11		٠	
			Uni	Units: UGL			
	Site ID	EHA3	EHA3	OHM-P11-32	OHM-P11-32	OHM-P11-32	OHM-P11-32
	Field Sample ID	MFP11EH2	MXP11EH2	MF1132X1	MFP11322	MX1132X1	MXP11322
	Sample Date	11/30/93	11/30/93	08/25/93	11/30/93	08/25/93	11/30/93
	Parameter .	3					
TAL METAL	Aluminum	15.7 BJ	122	< 25.0	20.6 BJ	1200	1350
	Antimony	4.82 BJ	< 5.00	9.06 B	< 5.00	< 5.00	< 5.00
	Arsenic	< 2.00	3.54	< 2.00	< 2.00	2.13 J	2.08
	Barium	< 10.0	< 10.0	< 10.0	< 10.0	9.06 J	12.3
	Beryllium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
	Calcium	8360	8290	5620	5200	0/09	5480
	Chromium	< 10.0	< 10.0	< 10.0	< 10.0	5.83 J	< 10.0
	Cobalt	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
	Copper	4.21 Ji	< 10.0	< 10.0	4.08 Ji	< 10.0	6.18 J
	Iron	17.0 BJ	745	< 25.0	13.3 BJ	1330	1630
	Lead	< 5.00	1.45 BJ	< 5.00	< 5.00	4.90 Ji	3.01 BJ
	Magnesium	1090	1180		294 J	583	909
	Manganese	9.19 B	14.0	3.09 BJ	2.58 BJ	15.9	17.2
	Nickel	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
	Potassium	4560 !	4280	2720	2390	2580	3120
	Sodium	17400	16100	2730	2550 B	2240	2950 B
	Vanadium	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
	Zinc	12.6 BJ	224 !	8.95 BJ	9.33 BJ	26.5 B	216 !
NA	Bis(2-ethylhexyl)phthalate		5.60 J				< 10.0
TPHC	Total Petroleum Hydrocarbons		< 2000				< 2000

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only) I= Retinated value I - Pecult bias low

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected.

Date: 10/77/04	V		3hle: 4-x	X-7.		rage 1 of 1
File Type: CC	Mic		Chemical Summary Report For Groundwater	enort For Groundwa	ater	Part 4 of 4
Site Type: WEL	5.W EI:1	)	Site	P11		
Sile Type: WELL	777		Units	Units: UGL		
	Site ID	OHM-P11-33	OHM-P11-33	OHM-P11-33	OHM-P11-33	
	Field Sample ID	MF1133X1	MFP11332	MX1133X1	MXP11332	
	Sample Date	08/25/93	11/30/93	08/25/93	11/30/93	
Test	Parameter.					
TAL METAL		66.7 B	106 B	1180	553	
	Antimony	3.59 BJ	< 5.00	< 5.00	< 5.00	
	Arsenic	6.50	2.60 !	5.73 J	2.83	
	Barium	< 10.0	< 10.0	7.13 J	< 10.0	
	Beryllium	< 5.00	< 5.00	0.414 Ji	< 5.00	
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	
	Calcium	29100 !	15300	28400 !	15200	
	Chromium	< 10.0	< 10.0	5.04 J	< 10.0	
	Cobalt	< 10.0	< 10.0	11.8	< 10.0	
	Copper	2.26 J!	< 10.0	5.88 J	3.57 J	
	Iron	< 25.0	14.9 BJ	918		
	Lead	< 5.00	< 5.00	< 5.00	1.81 BJ	
	Magnesium	368 J	448 J	661	510	
	Manganese	1.47 BJ	5.69 B	16.0 K	9.38	
	Nickel	< 10.0	< 10.0	< 10.0	< 10.0	
	Potassium	2020	2050	2350	1930	
	Sodium	3610	2860 B	3220	3680 B	
	Vanadium	11.1	< 10.0	17.2	5.41 J	
	Zinc	8.41 BJ	5.39 BJ	21.2 B	180 !	
TCL BNA	Bis(2-ethylhexyl)phthalate				< 12.0	
TPHC	Total Petroleum Hydrocarbons	8			< 2000	
_						

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only)
J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected.

File Type: CGW Site Type: WELL	File Type: CGW Site Type: WELL	O	Chemical Summary Report For Groundwater Site: P13 Units: UGL	ury Report For Groundw Site: P13 Units: UGL	ater		Part 1 of 3
	Site ID	E3-P13-M01	E3-P13-M01	E3-P13-M01	E3-P13-M01	E3-P13-M02	E3-P13-M02
	Field Sample ID	MF1301X1	MFP13012	MX1301X1	MXP13012	MF1302X1	MFP13022
	Sample Date	08/25/93	11/29/93	08/25/93	11/29/93	08/24/93	11/30/93
Test	Parameter .						
TAL METAL	Aluminum	55.4 B	29.5 B	32000 !	8300 i	15.1 BJ	121 K
7	Antimony	6.76 B	6.24 B	2.39 Ji	12.3 !	12.3 B	6.85 B
	Arsenic	1.54 J	1.54 J	37.5 J	14.5	2.81	< 2.00
	Barium	26.6	35.6	i 861	73.2	12.3	32.6
	Beryllium	0.147 BJ	< 5.00	1.56 J	0.396 Ji	< 5.00	< 5.00
	Cadmium	< 5.00	< 5.00	3.45 Ji	< 5.00	< 5.00	2.97 J!
	Calcium	16100	11400	20700	13500	12100	21500
	Chromium	< 10.0	< 10.0	58.9	11.8	< 10.0	< 10.0
	Cobalt	< 10.0	< 10.0	25.0 !	6.07 J	< 10.0	< 10.0
	Copper	1.52 J	< 10.0	39.5	11.2 !	2.45 J!	< 10.0
	Iron	50.9 B	24.2 BJ	38000	8930 i	146 B	127 B
	Lead	< 5.00	< 5.00	80.2	21.9	< 5.00	< 5.00
	Magnesium	4240 !	1830	14200 !	4020	870	1850
	Manganese	102	89.1	515 !	186	271 !	47.0
	Nickel	< 10.0	< 10.0	48.4	14.7	< 10.0	< 10.0
	Potassium	2640	3040 B	9520	4560 K	2710	4980
	Sodium	23000	36200	23700	36600	4830	43900 !
	Vanadium	< 10.0	< 10.0	0.09	14.2	< 10.0	< 10.0
	Zinc	21.7 B	10.7 BJ	109 K!	44.2	79.8 B	18.8 BJ
TCL Pest	Endosulfan, A			< 0.080	0.030 U		
•	beta-BHC			< 0.080	< 0.020		
	delta-BHC			< 0.080	0.034 C		
TPHC	Total Petroleum Hydrocarbons			535 Ji	< 2000		

B= Attributable to field or laboratory contamination.

C= Confirmed on second column, U= Unconfirmed.

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only)
J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected.

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File Type: CGW Site Type: WELL	A 1	0	Chemical Summary R Sit	Chemical Summary Report For Groundwater	ter		Part 2 of 3
	יו			Site: P13			
			Unit	Units: UGL			
	Site ID	E3-P13-M02	E3-P13-M02	E3-P13-M03	E3-P13-M03	E3-P13-M03	E3-P13-M03
	Field Sample ID	MX1302X1	MXP13022	MF1303X1	MFP13032	MX1303X1	MXP13032
	Sample Date	08/24/93	11/30/93	08/25/93	11/30/93	08/25/93	11/30/93
Test	Parameter.			Local background	Local background	Local background	Local background
TAL METAL	Aluminum	269 K	i 0085	14.2 BJ	28.9 B	5440	157
	Antimony	< 5.00	< 5.00	10.7 B	< 5.00	< 5.00	< 5.00
	Arsenic	3.89 J	5.18	< 2.00	1.63 J	5.99 J	2.81
	Barium	15.7	8.09	37.7	10.2	69.3	10.3
	Beryllium	< 5.00	< 5.00	0.096 BJ	< 5.00	0.378 J	< 5.00
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
	Calcium	12200	21200	24900	15100	25500	15400
	Chromium	< 10.0	10.0 J	< 10.0	< 10.0	13.3	< 10.0
	Cobalt	< 10.0	4.46 J	4.68 J	< 10.0	7.72 J	< 10.0
	Copper	1.54 J	13.9	1.57 J	< 10.0	6.55 J	< 10.0
	Iron	445	i 0969	< 25.0	K K	0099	688
	Lead	< 5.00	2.71 BJ	< 5.00	< 5.00	3.11 J	1.61 BJ
	Magnesium	864	3540	2180	915	3900	954
	Manganese	270 !	133	124	172	210	165
	Nickel	< 10.0	8.17 J	< 10.0	< 10.0	15.5	< 10.0
	Potassium	2600	3820	3800	2540	4960	2130
	Sodium	4590	42400 i	43700	5650 K	42200	4780 K
	Vanadium	< 10.0	13.6	< 10.0	< 10.0	11.1	< 10.0
	Zinc	68.0 K!	416 !	21.6 B	13.0 BJ	27.0 B	11.6 BJ
TCL Pest	Endosulfan, A	0.028 U	< 0.020		The second secon	< 0.080	< 0.020
	beta-BHC	< 0.020	< 0.020			< 0.080	< 0.020
	delta-BHC	0.058	< 0.020			< 0.080	< 0.020
ТРНС	Total Petroleum Hydrocarbor	328 J	467 BJ			332 J	< 2000

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only)
J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected.

File Type: CG	W.		hemical Summary Report	Chemical Summary Report For Groundwater	ater	Part 3 of 3
File Type: CGW Site Type: WELL	ELL	,	Sir Summer Sir Sir Sir Sir Sir Sir Sir Sir Sir Si	Site: P13 Units: UGL		
	Site ID	E3-P13-M04	E3-P13-M04	E3-P13-M04	E3-P13-M04	
	Field Sample ID	MF1304X1	MFP13042	MX1304X1	MXP13042	
	Sample Date	08/24/93	11/29/93	08/24/93	11/29/93	
Test	Parameter.					
TAL METAL		· 34.8 B	52.1 B	2140	1110	
		2.49 BJ	< 5.00	< 5.00	< 5.00	
	Arsenic	< 2.00	1.12 J	< 2.00 J	0.830 J	
	Barium	< 10.0	< 10.0	23.9	20.9	
	Beryllium	< 5.00	< 5.00	0.175 J	< 5.00	
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	
	Calcium	2180	2130	3290	3410	
	Chromium	6.16 J!	< 10.0	< 10.0	< 10.0	9
	Cobalt	< 10.0	< 10.0	< 10.0	< 10.0	
	Copper	< 10.0	< 10.0	1.75 J	4.09 J	
	Iron	16.5 BJ	40.7 B	1560		
	Lead	< 5.00	< 5.00	< 5.00	1.19 BJ	1
	Magnesium	216 KJ	205 J	763	423 J	
	Manganese	32.0	20.5 K	63.1	32.3	
	Nickel	< 10.0	< 10.0	< 10.0	9.08 J	
	Potassium	S96 J	864 BJ	1180		è
	Sodium	2590	4260 B	2980	3520 B	
	Vanadium	< 10.0	< 10.0	_		
	Zinc	13.9 BJ	22.9 K	29.1 B	29.4 K!	
TCL Pest	Endosulfan.A			< 0.020	0.028 C	
	beta-BHC			< 0.020	0.033 C	
	delta-BHC			< 0.020	0.033 C	
TPHC	Total Petroleum Hydrocarbons	S		< 2000	< 2000	

! = Exceeds range found in local background well E3-P13-M03 (metals, TPHC only)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected.

Date: 10/27/94	4		Table	Table: 4-10			Page 1 of 1
File Type: CSW	W	כ	nemical Summary Re	Chemical Summary Report For Surface Waters	iters		
Site Type: POND	QNo		Sit Unit	Site: P11 Units: UGL			
	Site ID	E3-P11-D01	E3-P11-D01	E3-P11-D02	E3-P11-D03	E3-P11-D04	E3-P11-D04
	Field Sample ID	WDP11012	WXP11012	WXP11022	WXP11031	WXP11042	WXP11043
	Sample Date	12/01/93	12/01/93	12/01/93	09/15/93	12/02/93	4/26/94
Test	Parameter.						
TAL METAL	Aluminum	4090 Ji	2910 J!	342 J	235 J	22000 Ji	73.0
	Arsenic		1.94 J	1.98 J	7.01	90.8	<2.00
	Barium	78.3 J!	52.3 Ji	14.2 Ji	7.86 J	512 Ji	7.85 J
	Beryllium	0.288 J	0.217 J	< 5.00	< 5.00	3.78 J	0.268 Ji
	Cadmium	< 5.00	< 5.00	1.46 J	< 5.00	4.23 J	<5.00
	Calcium	8430	7210	11200 !	4470	140000 !	10500
	Chromium	3.89 Ji	< 10.0	< 10.0	< 10.0 K	46.3	<10.0
	Cobalt	3.10 J	3.18 J	< 10.0	2.76 J	110 !	<10.0
	Copper	10.5 !	7.22 J	< 10.0	< 10.0	1961	4.03 Ji
	Iron	2800 J	1830 J	220 J	1580	130000 Ji	330
	Lead	21.6 !	13.0	2.16 BJ	1.33 J	330 i	1.24 J
	Magnesium	1710	1640	i 0961	840	12300 !	2310 !
	Manganese	544	515	71.4	165 !	9500 !	24.5
	Mercury	< 0.200	< 0.200	< 0.200	< 0.200	0.244	<0.200
	Nickel	< 10.0	< 10.0	< 10.0	< 10.0	260 !	<10.0
	Potassium	1210 B	1070 B	1370 B	885 J	4980 K!	2120 !
	Selenium	< 2.00	< 2.00	< 2.00	< 2.00	6.78	<2.00
	Silver	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00	2.31
	Sodium	3290 B	3250 B	5420 B	3490	8130 K	9340
	Vanadium	10.1	5.64 Ji	< 10.0	< 10.0	88.6	2.84 J
	Zinc	· 82.7 !	65.7 !	35.0	30.7	940 !	49.8 I
TCL VOA	Acetone	< 10.0	12.0	< 10.0	< 10.0	< 10.0	
TPHC	Total Petroleum Hydrocarbons						<2000
WOP	Total Suspended Solids						200

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exceeds Background (metals only)

Date: 10/27/94			Table: 4-10	4-10		Page 1 of 1
File Type: CSW	*	5	Chemical Summary Report For Surface Waters	port For Surface Wa	iters	Part 2 of 2
Site Type: POND	QD.		Site	Site: P13 Units: UGL		
	Site ID	E3-P13-D01	E3-P13-D03	E3-P13-D04	E3-P13-D05	
	Field Sample ID	WX1301X1	WXP13032	WXP13042	WXP13052	
	Sample Date	08/02/93	12/01/93	12/01/93	12/01/93	
Test	Parameter.					
TAL METAL	Aluminum	501 Ji	746 J!		207 J	
	Arsenic	4.60 !	_,		1.41 J	
	Barium	24.6	11.8 J!		9.31 J	
	Calcium	11000 !	4690		8450	
	Copper	5.60 J	4.08 J		< 10.0	
	Iron	5100 !	1420 J		328 J	
	Lead	11.1	12.3		< 5.00	
	Magnesium	2610 !	533		1760	
	Manganese	91.8	33.3		48.3	
	Potassium	6010	668 BJ			
	Sodium	6350	3960 B		6350 K	
	Vanadium	3.38 J	3.51 J		< 10.0	
	Zinc	10.8	181		23.9 !	
TCL Pest	P,P-DDD	0.016 JC	0.018 JC	< 0.048	< 0.040	
	P,P-DDE	0.019 JC	0.055 C	< 0.048	< 0.040	
	P,P-DDT	< 0.040	0.263 C	< 0.048	< 0.040	

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exceeds Background (metals only)

Date: 10/27/94	4		Table: 4-11	4-11			Page 1 of 2
File Type: CSE	H		Chemical Summary Report For Sediments	Report For Sediment	S		Part 1 of 1
Site Lype: POIND			Units	Site: P11 Units: UGG			
	Site ID	E3-P11-D01	E3-P11-D02	E3-P11-D03	E3-P11-D04	E3-P11-D04	
	Field Sample ID	DX1101X1	DX1102X1	DXP11031	DXP11042	DXP11043	
	Sample Date	08/03/93	08/03/93	09/15/93	12/02/93	4/26/94	
Test	Parameter.						
TAL METAL	Aluminum	*i 00L8	6300 !	2880	3730	2490	
	Antimony	<0.500	<0.500	<0.500	<0.500	1.01 Ji*	
	Arsenic	2.81	2.38 !	4.84	11.6 !*	2.35 !	
	Barium	19.5	25.7 !	6.20 J	36.4 !	18.4	
	Beryllium	0.205 Ji*	0.294 J!	0.146 JL	0.282 Ji*	0.201 Ji*	
	Calcium	< 500	1610 !	343 J	*i 00501	2900	
	Chromium	2.87 J	6.62	5.20	J.77 J	3.72 J	
	Cobalt	2.23	2.34	4.06 !	5.18 Ji	2.15	
	Copper	8.13 !	8.31 !	2.50 L	5.65	5.99	
	Iron	0069	3500	0669	4200	3390	
	Lead	34.0 !	31.0 !	7.17 !	5.13 !	33.0 !	
	Magnesium	409 J	731 J	i 00288	1110 J	470 J	
	Manganese	14.4	30.9	148 !		31.7 !	
	Nickel	4.28	6.33 !	6.12	26.0 !*	5.97	
	Potassium	169 BJ	363 KJ	205 BJ	< 200	<200	
	Selenium	0.572 !*	0.724!	< 0.200 L	3.17 !*	1.08 Li*	
	Silver	< 0.200	< 0.200	< 0.200	1.89 !*	<0.200	
2	Vanadium	10.7	10.3	7.16	9.79 J	2.94 J	
	Zinc	12.6	23.2	17.6 J	21.8 !	1 6.64	
TCL BNA	Anthracene	< 2.00	< 0.330	0.210 J	< 0.330	The second secon	
	Benzo(a)anthracene	< 2.00	< 0.330	1.20	< 0.330		8. 8.00 km s 20 km s 20 km
	Benzo(a)pyrene	< 2.00	< 0.330	0.870	< 0.330		
2	Benzo(b)fluoranthene	< 2.00	< 0.330	1.40	< 0.330		
÷	Benzo(ghi)perylene	< 2.00	< 0.330	0.300 J	< 0.330		
	Benzo(k)fluoranthene	< 2.00	< 0.330	0.550	-< 0.330		

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)
! = Exceeds range found in background stream sediments (metals, pests, TPHC) * = Exceed range found in Background pond (metals, pests) E3-P11-D01/D04 only L= Result bias low. R= Result rejected. B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value.
K= Result bias high.

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Date: 10/27/94	4		Table: 4-11	4-11			Page 2 of 2
File Type: CSE Site Type: POND	E NO		Chemical Summary I	Chemical Summary Report For Sediments Site: P11			Part 1 of 1
			Units	Units: UGG			
	Site ID	E3-P11-D01	E3-P11-D02	E3-P11-D03	E3-P11-D04	E3-P11-D04	
	Field Sample ID	DX1101X1	DX1102X1	DXP11031	DXP11042	DXP11043	
	Sample Date	08/03/93	08/03/93	09/15/93	12/02/93	4/26/94	
Test	Parameter.						
TCL BNA	Chrysene	< 2.00	< 0.330	1.00	< 0.330		
	Dibenzo(a,h)anthracene	< 2.00	< 0.330	0.150 J	< 0.330		
	Fluoranthene	< 2.00	< 0.330	1.80	< 0.330		
	Indeno(1,2,3-cd)pyrene	< 2.00	< 0.330	0.400 J	< 0.330		
	Phenanthrene	< 2.00	< 0.330	0.510	< 0.330		
	Pyrene	< 2.00	< 0.330	1.40	< 0.330		
TCL Pest	P,P-DDD	0.010 C!	0.100 C!	0.004 U!	< 0.020		
	P.P-DDE	0.022 C!	0.079 C!	0.015 C!	< 0.020		
	P,P-DDT	< 0.010	0.038 JC!	0.010 CK!	< 0.020		
	alpha-BHC	< 0.005	< 0.010	0.001 JC!	< 0.010		
TOC	Total Organic Carbon	143000	63800	12000		107000	
TPHC	Total Petroleum Hydrocarbor	26.0 Ji	< 20.0	< 20.0	106	<20.0	

* = Exceed range found in Background pond (metals, pests) E3-P11-D01/D04 only ! = Exceeds range found in background stream sediments (metals, pests, TPHC)
B= Attributable to field or laboratory contamination.
J= Estimated

C= Confirmed on second column, U= Unconfirmed.

L= Result bias low. R= Result rejected. J= Estimated value. K= Result bias high.

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NOOT TOTAL	.!		•				
Site 1 ype: POIND	QN		Site Units	Site: P13 Units: UGG			
	Site ID	E3-P13-D01	E3-P13-D01	E3-P13-D02	E3-P13-D03	E3-P13-D04	E3-P13-D05
	Field Sample ID	DD1301X1	DX1301X1	DX1302X1	DX1303X1	DX1304X1	DX1305X1
	Sample Date	08/02/93	08/02/93	08/02/93	08/03/93	08/03/93	08/03/93
Test	Parameter.						
TAL METAL	Aluminum	5280 i	4100	4500	3700	4400	2500
٠	Arsenic	11.2 !*	*i 98.6	3.46 !	4.71	37.0 !	0.941
	Barium	\$9.5 !*	\$i 0.65	14.7	16.4	16.4	10.9
	Beryllium	*if L69.0	0.566 Ji*	0.198 Ji	0.166 J	0.365 J!	0.062 J
	Cadmium	< 0.500	< 0.500	< 0.500	1.43 K	0.287 BJ	< 0.500
	Calcium	*i 20200	19400 i*	; 995	480 J	1170	737
	Chromium	11.3 J!	9.79 Ji	9.78	15.2 !	99.7	4.23
	Cobalt	10.7	9.10 !	4.44	1.07	3.17	1.39 J
	Copper	34.0 i*	9.10 !	5.42	29.6	4.37	2.21
	Iron	140000 !*	13000 !	7200	i 00097	0099	3000
	Lead		*i L'69	i 00'9	23.0 !	23.0 !	7.21
	Magnesium	2350 Ji*	1980 J*	1990	1450	1170	962
	Manganese	9.99	*i 9.9 <i>L</i>	77.2	84.3	42.9	31.9
	Nickel	29.1 i*	23.9 i*	8.51 !	12.0	7.89	4.02
	Potassium	< 200	< 200	1060	699	424 K	311 K
	Selenium	2.65 !*	1.94 !*	< 0.200	< 0.200	0.537!	< 0.200
	Vanadium	30.9 i*	22.9 i*	13.0	11.4	11.4	4.90
	Zinc	569 i*	277 !*	15.9	370 !	15.0	12.0
TCL BNA	Benzo(b)fluoranthene	< 2.00	< 2.00	< 0.330	< 2.00	< 0.330	0.082 J
	Fluoranthene	< 2.00	< 2.00	< 0.330	< 2.00	< 0.330	0.120 J
	Pyrene	< 2.00	< 2.00	< 0.330	< 2.00		
TCL Pest	P.P-DDD	0.690 Ci*	0.760 Ci*	0.008 JC!	0.170 C!	0.020 C!	
	P,P-DDE	0.480 Ci*	0.540 Ci*	0.022 C!	0.120 C!	0.037 C!	0.022 C!
	P,P-DDT	0.110 JC!*	0.150 C!*	0.012 C!	0.230 C!	0.019 C!	< 0.008
TOC	Total Organic Carbon	592000	628000	12800	26200	79800	35400
TPHC	Total Detroleum Hydrocarbor	551 1	1 566	< 20.0	263	< 20.0	< 20.0

* = Exceed range found in Background pond (metals, pests) E3-P13-D01 only L= Result bias low. J= Estimated value. ! = Exceeds range found in background stream sediments (metals, pests, TPHC) B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

R= Result rejected. K= Result bias high.

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### 5. CONTAMINANT FATE AND TRANSPORT

The fate and transport of chemicals in the environment is dependent both on properties of the contaminants and on characteristics of the environment. In general, the contaminant's properties dictate the fate of the chemical (i.e., in which phase(s) it will reside). The characteristics of the environment, on the other hand, are primarily responsible for the potential transport mechanisms. There are certainly exceptions to this generality; for example, the organic content of the soil (an environmental characteristic) has an effect on how strongly certain organic compounds will sorb onto the solid phase (a potential fate.)

The following two sections summarize potential fate and transport mechanisms in general. Section 5.3 is a more in-depth discussion of the contaminants of potential concern (COPCs) at Site P11/P13.

#### 5.1 POTENTIAL CONTAMINANT FATES

There are four phases at Site P11/P13 in which a contaminant can reside in the environment. It can be found in the atmosphere or soil gas as a vapor. It may be dissolved in the aqueous phase, either in underlying groundwater or in surface water bodies such as the tributary to Honey Brook. It can sorb onto solid particles, such as unsaturated soil, aquifer solids, or airborne particulates. Finally, it may exist in its own phase, either in the solid or liquid form. An examination of the physical and chemical properties of each contaminant can help in predicting in which phase(s) it is likely to be found. Contaminant transport can then be deduced from an understanding of the site characteristics. The following section summarizes the transport possibilities at Site P11/P13.

### 5.2 TRANSPORT MECHANISMS AT SITE P11/P13

Contamination at Site P11/P13 was probably introduced into the environment through the surficial soils (see Section 5.3). However, a variety of processes could redistribute the contaminants between phases, which may increase the possibility of transport, From the surface soils, volatile compounds tend to partition to the atmosphere, essentially removing them from other media of concern. Strongly sorbing compounds would bind to surficial particles, but could still be mobilized as suspended particulate matter in surface flow after large rainfall events. Soluble components can be mobilized in the aqueous phase, both in surface water and groundwater. Surface waters at Site P11/P13 flow east and south to adjacent wetlands, which are drained by Honey Brook. Soluble contaminants may reach the saturated zone via infiltrating rainwater, because the soils at Site P11/P13 are permeable and well-drained. From here they would flow with the groundwater, which ultimately discharges into a seep and wetland area approximately 500 feet north of the entrance to the site from White Pond Road. The wetland drains to an unnamed stream flowing north to the Assabet River.

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### 5.3 FATE AND TRANSPORT OF SITE P11/P13 CONTAMINATION

Site history indicates the following usages of Site P11/P13: ordnance research and development, laboratory research on foamed plastics, flame testing, meteorological projects, insecticide and rodenticide research, and fire fighting training activity. It is suspected that some dumping and spilling of research materials may have occurred in the area west of Building T405, which may have introduced organic chemicals into the surface soils. Other possible contaminants at the site include explosive organic compounds, pesticides, and TPHC, including associated compounds such as PCBs and PAHs. Again, it is likely that such contamination would have been introduced into the surface soils. However, there were several underground storage tanks in the area, some of which have been removed. Therefore, it is also possible that TPHC was introduced into the subsurface soils or groundwater.

Site sampling revealed the presence of a wide variety of contamination at Site P11/P13. However, the purpose of this section is to discuss the fate and transport of those compounds which may have contributed significantly to site-related contamination. Therefore, only those contaminants identified by the Human Health Risk Assessment (HHRA) and the Ecological Risk Assessment (ERA) as being of concern are included in this chapter. The HHRA considered virtually every contaminant that was detected as a contaminant of potential concern (COPC). Only a few metals and pesticides which were not detected above background concentrations were not included in the COPC list (see Section 6). However, very few contaminants were identified by the HHRA as posing potentially significant risks: arsenic, beryllium, lead, manganese, chlordane, chrysene, heptachlor epoxide, and PCBs (1254 and 1260). In the ERA, it was decided to limit the COPC list to those contaminants to which ecological receptors may be highly sensitive. Therefore, before the ERA was conducted, the data were screened against background and various risk-based criteria; only those contaminants that exceeded both background and risk-based criteria with sufficient frequency were considered COPCs. In addition, several metals were excluded from the COPC list because they are not considered site-related, or the risk-based criteria were not considered appropriate (see Section 7 for more detail). The only contaminants that passed through the screening and were considered in the ERA were: arsenic, lead, and zinc. Of these, only zinc was found to exceed the acceptable risk level. Nevertheless, all three ERA COPCs are discussed because they passed the screening. On the other hand, only those COPCs identified by the HHRA as posing potential risk are discussed, since virtually no screening was applied in creating its COPC list.

## 5.3.1 Organics

For organic constituents, it is useful to consider contaminant properties such as aqueous solubility  $(C_{i,aq})$ , Henry's constant (H), and the octanol-water partitioning coefficient  $(K_{ow})$ . In general, compounds with a high  $C_{i,aq}$  also have a high H. If in the groundwater, they are likely to be mobilized in the aqueous phase, perhaps slowly volatilizing into the soilgas. Once in the surface water, however, they will ultimately reach the atmosphere. Compounds with a large  $K_{ow}$  are usually not very soluble or volatile. They may exist primarily in their own phase, or may sorb onto organic-rich soils and sediments. They will then be

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immobilized unless the solids themselves are transported as suspended solids or airborne particulates.

These three properties can be used to predict the fate of organic contaminants. To analyze sorption, an empirical relationship was developed by Karickhoff *et al.* (1979) relating the ratio of the concentration of a solute sorbed onto aquifer particles to the concentration of solute in solution. For solute i:

$$K_d = \frac{C_{i,solid}}{C_{i,aq}} = (0.63 \times 10^{-6} \frac{m^3}{g})(k_{ow})(f_{oc})$$

where  $K_d$  = distribution coefficient  $C_{i, solid}$  = gram of solute sorbed per gram of solid  $C_{i, aq}$  = gram of solute dissolved per  $m^3$  of solution  $0.63 \times 10^{-6} \text{ m}^3/\text{g}$  = empirically determined constant  $K_{ow}$  = octanol/water partitioning coefficient  $f_{oc}$  = mass fraction of organic carbon in solid.

The dimensions of this coefficient make it difficult to judge what would be considered strongly or weakly sorbing. It is more useful to consider a unit volume in the aquifer and calculate the ratio of contaminant mass sorbed onto solids to contaminant mass dissolved in groundwater in the volume. This is calculated by multiplying the distribution coefficient by several factors.  $P_b$  is the bulk density of aquifer solids, that is, the mass of solids per unit volume. If the porosity of the aquifer is n, then (1-n)/n is the ratio of the volume of aquifer solids to the volume of groundwater in the unit volume. Thus,

$$M = K_d \frac{P_6(1 - \epsilon)}{\epsilon} = \frac{mass \ i \ sorbed}{mass \ i \ dissolved}$$
 in the unit volume

M, the mass distribution of solute i in the aquifer, essentially represents the tendency of the compound to exist in either sorbed or dissolved form. When M=1, then at equilibrium there will be equal amounts of solute sorbed and dissolved. Every time uncontaminated water enters the unit volume, half of the solute would desorb and enter solution. Because water is continuously moving through most aquifers, this would represent a mobile, non-sorbing contaminant. When M=100, one percent of the solute is dissolved at equilibrium. Then, as fresh water is introduced into the volume, only one percent of the solute would desorb. Still, the contaminant would not persist in the solids over the very long term, and this contaminant is considered moderately sorbing. Contaminants with  $M>10^4$  can be considered strongly sorbing. They would be expected to persist, essentially immobilized, sorbed to aquifer solids. Such compounds would also sorb strongly to sediments and surficial soils with sufficient organic content. However, they could be mobilized in these media either as suspended solids or airborne particulates.

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A particularly useful representation of sorption tendency is derived from the model of contaminant flow through porous media. When sorption is accounted for in the model, the following "retardation factor" relates the groundwater velocity to the contaminant velocity (Tchobanoglous 1987):

$$R = \frac{V_{gr}}{V_{con}} = \frac{K_d P_b (1 + \epsilon)}{\epsilon}$$

where  $v_{gr}$  = average velocity of groundwater, and  $v_{con}$  = average velocity of contaminant front

The reciprocal of this term (1/R), therefore, represents the ratio of contaminant velocity to groundwater velocity (Freeze and Cherry 1979). That is, it is an estimate of how much the contaminant is slowed because of sorption effects. If a strongly sorbing compound  $(R > 10^4)$  is within the aquifer, then, as groundwater flows through an uncontaminated area, almost all of the dissolved portion would be expected to sorb out. Therefore, the contaminant itself will be essentially immobile. For a completely non-sorbing compound,  $K_d = 0$ , R = 1, and the contaminant moves with the same velocity as the groundwater. Contaminants with a retardation factor from 10 to 1,000 can be considered moderately to considerably sorbing. Those with R = 100 to 1,000 clearly will move much more slowly than groundwater. However, over the very long term, if groundwater movement is fast, then even these contaminants will exhibit some mobility.

To evaluate the tendency of a compound to volatilize, the Henry's constant is calculated for that compound. The dimensionless form of this constant is the ratio of the molar concentrations of the solute in vapor to that in solution, and is calculated as:

$$H = \frac{P_i^{sat}}{C_i RT}$$

where  $P_i^{\text{sat}} = \text{vapor pressure of solute } i \text{ (atm)}$  $C_i = \text{solubility of solute } i \text{ (mol/L)}$ 

 $R = ideal gas constant = 0.0821 \frac{atm L}{mol K}$ 

T = temperature (K)

For example, consider the case of a closed vessel with equal quantities of water and air. If, for a given compound, the dimensionless Henry's constant equaled one, then equal quantities of the compound would be dissolved and vaporized. Of course, in nature, if a compound is in the surface water, for example, there is virtually an infinite quantity of air in which to vaporize. For this compound, it could be assumed that all of it reached the vapor

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phase. These contaminants will be considered highly volatile. Contaminants with  $H = 10^{-2}$  are moderately volatile, and those with  $H < 10^{-5}$  are insignificantly volatile.

Literature values for the aqueous solubility, vapor pressure, and octanol/water partitioning coefficient of the organic contaminants of concern found at Site P11/P13 are presented in Table 5-1. Henry's constants were calculated from the vapor pressure and solubility, and were made dimensionless using a temperature of 20°C (293 K). Mass distribution and retardation factors were calculated using  $P_b = 2.0 \times 10^6$  (Tchobanoglous 1987), v = 0.30 (Freeze and Cherry 1979), and  $f_\infty = 0.005$  (average of five subsurface soil organic content samples at Site P11/P13). They are also listed in Table 5-1.

## 5.3.1.1 Polychlorinated Biphenyls (PCBs)

PCBs are typically thought of as being immobile in most systems, sorbing strongly to solid particles, whether in surface soils, sediments or aquifer solids. As their physical/chemical properties indicate they are practically insoluble and have a considerable tendency to sorb. However, because of the low organic content of the soils (approximately 0.5 percent in an average of five subsurface soil samples), their retardation factors are 10 to 100 times lower than they would be in more highly organic sediments. Therefore, they could leach very slowly with infiltrating rainwater (Agency for Toxic Substances Disease Registry (ATSDR) 1993). Furthermore, their Henry's constants indicate that they have a significant potential to volatilize from the aqueous phase. While sorbed to soils, this tendency is attenuated considerably. However, because of the weaker sorption potential of this low-organic soil, the vaporization rate from soil is probably higher than otherwise. When the soil is wet, the rate may be higher still, if some PCB dissolves.

PCB compounds (particularly the heavier ones like 1254 and 1260) are not transformed quickly, either biotically or abiotically. In the vapor phase, the primary transformation mechanism is probably photolysis with hydroxy radicals, with a half-life on the order of months (ATSDR 1993). Biodegradation in soil and water is possible, both aerobically and anaerobically, but is also very slow. The heavier PCBs, again, are resistant to biotransformation. However, biodegradation is faster in low-organic soils, probably because more PCB molecules will be available in the aqueous phase.

Taken together, the following fate and transport scenario can be constructed. PCB 1254 and 1260 were introduced into the surface soils as a result of some type of waste oil deposit (perhaps from a leaky transformer). Most of the PCBs became sorbed to the solid particles upon contact. PCB compounds tend to sorb strongly; however, because the organic content of the soils is low, they may be susceptible to redistribution. The most significant mechanism is probably vaporization. When the soil is wet after rainfall events, some of the PCBs may dissolve; however, because of their large Henry's constants, it is more likely that they will volatilize than be transported in the aqueous phase. Of course, they can be mobilized with surface flow while attached to particulate matter, but over the long term, they will probably volatilize to the atmosphere. Once in the atmosphere, they may be photodegraded slowly. In summary, the PCBs will remain in the surface soils, immobilized,

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	PHY	'SICAL/CHER	Tab MICAL PROPE	Table 5-1 PHYSICAL/CHEMICAL PROPERTIES OF THE ORGANIC COPCs	ORGANI	c copcs	
Contaminant	Molecular Weight ^a g/mol	Aqueous Solubility ^a mg/L	Vapor Pressure ^a mmHg	Henry's Constant ^b [-]	Log Kow ^a [-]	Mass Distribution ^c M, [-]	Retardation Factor ^c R, [-]
PCB-1254	328	0.012	7.71 x 10 ⁻⁵	0.115	6.5	4.65 x 10 ⁴	6.64 x 10 ⁴
PCB-1260	375.5	2.7 x 10 ⁻³	4.05 x 10 ⁻⁵	0.308	8.9	9.28 x 10 ⁴	1.33 x 10 ⁵
Chlordane	409.76	0.056	2.55 x 10 ^{-5d}	1.02 x 10 ⁻²	5.54	5.10 x 10 ³	7.28 x 10 ³
Chrysene	228.3	1.8 x 10 ⁻³	6.3 x 10 ⁻⁹	4.37 x 10 ⁻⁵	5.61	$6.03 \times 10^3$	8.61 x 10 ³
Heptachlor Epoxide	389.40	0.275	2.6 x 10 ⁻⁶	2.01 x 10 ⁻⁴	5.40	3.69 x 10 ³	5.27 x 10 ³

^a Source ATSDR, 1992-1993. ^b Calculated from vapor pressure and solubility. ^c Calculated using  $P_b=2.0 \times 10^6 \ g/m^3$ ; v=0.30;  $f_{oc}=0.005$ . ^d Average for cis- and trans-isomers.

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for a long time. The primary removal mechanism will be vaporization, and there is little potential for mobilization in the aqueous phases.

### 5.3.1.2 Pesticides and Related Compounds

Chlordane and heptachlor epoxide were identified in the HHRA as posing potential risk in groundwater. Chlordane is actually a mixture of two stereoisomers: cis-chlordane (alpha-chlordane) and trans-chlordane (gamma-chlordane). Both were detected at Site P11/P13 at concentrations approaching their risk-based concentrations (RBCs). Although they have slightly different properties, they are similar enough to be discussed together. Chlordane acts similarly to the PCBs discussed above. It has a low solubility and moderately high tendencies to sorb and volatilize. In soils, it can be expected to sorb fairly strongly, but volatilization should be a significant removal mechanism. Because these soils have a low organic content, volatilization is even more important, particularly when the soils are moist. Like the PCBs, chlordane is not expected to leach, but if some enters the aqueous phase, it will volatilize more quickly than it will resorb (ATSDR 1993). In the vapor phase it is transformed by photolysis and oxidation. Little study has been done regarding transformation in water, but it appears that volatilization is more important than degradation (ATSDR 1993). Chlordane was probably introduced into the surface soils as a result of facility-wide pest control. It will persist for a relatively long period of time in the soils, and will be slowly released to the atmosphere. It is unlikely that leaching to groundwater and subsequent mobilization is significant.

Heptachlor epoxide has a low solubility, a moderate tendency to sorb, and fairly low Henry's constant. Like the PCBs and chlordane, it will persist for a long period of time, sorbed to surface soils. It does not have a significant tendency to leach nor a tendency to volatilize. Nevertheless, vaporization may be the primary removal mechanism from soil (ATSDR 1993), particularly since the soils at Site P11/P13 have such a low organic content.

Heptachlor epoxide is a degradation compound of the organic pesticides heptachlor, Heptachlor is biodegradable in both soil and water. Its major degradation compound, heptachlor epoxide, however, is much more resistant to biotransformation (ATSDR 1993). Therefore, it is possible that heptachlor was introduced into the surface soils as a result of site-wide pest control. However, it was rapidly degraded, leaving behind the recalcitrant compound, heptachlor epoxide. This is not only resistant to biotransformation, but also does not transfer quickly to either the aqueous or the vapor phase. Therefore, it can be expected to remain, virtually immobilized, in the surficial soils.

### 5.3.1.3 Chrysene

Chrysene was identified in the HHRA as posing potential risks in soils. It is an example of a PAH compound. PAH compounds are found in many different environmental media: atmosphere, surface water, sediments, groundwater, surficial and subsurficial soils, as well as organisms. They are sometimes split into categories based on their molecular weight, because similarly weighted PAH compounds possess similar physical and chemical properties. Chrysene is considered a heavy PAH compound. It is typical to find PAH compounds

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together because all are products of incomplete combustion of petroleum hydrocarbons and coal. The fact that the heavier PAH compounds (like chrysene) are often detected in greater concentrations may be because they have less potential for migration and transformation.

Chrysene has a low solubility and low Henry's constant, suggesting that it does not partition either to the aqueous or vapor phase. Indeed, its retardation coefficient suggests a strong tendency to sorb onto solids. In the atmosphere, it is likely to be sorbed to airborne particulates, and will be returned to the surface primarily by dry deposition. Because it usually sorbs to sub-micron particles, its residence time in the atmosphere may be on the order of weeks, and it could travel long distances. In aqueous environments, it will sorb to particles, such as suspended sediments, suspended particulates, or grain surfaces. It is therefore unlikely that chrysene will be mobile in water. Because the organic content of the surficial soils is low at Site P11/P13, however, it may be removed slowly by infiltrating rainwater and volatilization.

In soils and sedimentary environments, biodegradation is the major destructive process, but is influenced by a number of environmental factors, including the availability of oxygen. Therefore, if it reaches the saturated zone where oxygen may be limited, chrysene may be quite persistent. Photo-oxidation and chemical oxidation by hydroxy radicals are also potential transformation possibilities. Although PAHS may accumulate in biotic systems, many organisms are able to metabolize them. However, all of these transformation mechanisms are more readily active on the lighter PAH compounds than the heavier ones like chrysene.

For these reasons, chrysene is likely to behave similarly to the PCBs. It was probably introduced into the surface soils as a result of combustion activities, as from ordinary vehicular use. Once introduced into this solid medium, it is likely to remain there, sorbed. Because the organic content is so low, there may be some loss to vaporization and dissolution. In addition, some chemical and biological transformation may occur. In general, however, the bulk of the chrysene will remain in the soils, immobilized, for a considerable period of time.

### 5.3.2 Inorganics

Metals can volatilize into the air, sorb onto particles, enter the aqueous phase or exist as an insoluble solid or liquid. However, their physical/chemical properties (H,  $C_{i,aq}$ ,  $K_{ow}$ ) depend on the oxidation states they are in, and on the type of complexes that exist for a given metal. These, in turn, are determined by the properties of the environment itself, such as pH, redox potential, and water quality. For example, lead can exist in three oxidation states, two of which, Pb(IV) and Pb(0), form solids that are so insoluble (PbO_{2(s)} and Pb_(s)) that virtually no other species exist. However, in most natural systems, Pb(II) is dominant and a variety of soluble compounds may form. Accurately predicting the existing form(s) of a metal in a given environment requires detailed knowledge of that environment's chemistry. Nevertheless, trends can be deduced from a more limited characterization. Unless otherwise noted, the information that appears below was found in the ATSDR Toxicological Profiles, 1992 to 1993.

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### 5.3.2.1 Arsenic

Arsenic was identified by the HHRA as posing a potential risk in both soils and groundwater, and by the ERA as being a COPC in sediments. Analysis of arsenic's transport in the environment is complicated considerably because its redox state can change frequently in common environmental conditions due both to chemical and biological transformation. Its ground state, the insoluble and sorbing As(0) is rarely observed. In soils where oxygen is present, the fully oxidized As(V) results, generally as arsenate (AsO₄³⁻), which forms insoluble salts with aluminum, barium, calcium, and iron. These will sorb to soil particles. and will be mobilized only with dust or as suspended particulates in surface flow. However, chemical redox reactions as well as microbial transformation can reduce arsenic to more mobile forms. For example, in slightly reducing conditions, the arsenate may be reduced chemically to arsenite (As⁽⁺³⁾O₃³⁻), or biologically to (CH₃)₂As⁽⁺³⁾O₂H through biological methylation. After large rain events, even the surficial soils could be slightly reducing. Methylated arsenic is considerably soluble, and if it reaches the saturated zone (possibly anaerobic), highly reducing conditions could further reduce the As(III) to As(-III), again through biomethylation. As⁽⁻³⁾(CH₃)₂ is soluble and could be transported in groundwater. Methylated arsenic is also considerably volatile. However, if it were to reach the atmosphere, it would probably be oxidized to As(V) (as arsenate) or As(III) (as arsenite), attach to particulates, and eventually drop out of the vapor phase. Nevertheless, biomethylation represents a possible mechanism for the transport of arsenic at Site P11/P13.

It appears that most of the arsenic is actually sorbed. Its detection at high concentrations in sediments is hardly surprising, given that the average organic content of these samples was almost 18 percent. Filtered and unfiltered groundwater samples provide additional evidence. The maximum concentration of arsenic found in filtered groundwater was  $6.5 \mu g/L$  versus  $37.5 \mu g/L$  for unfiltered. The dissolved arsenic was found in wells OHM-P11-33 and E3-P13-M02. From here, the groundwater moves south, toward Honey Brook. However, it is likely that the arsenic found at elevated levels at Site P11/P13 is due to natural fluctuation, and not to site activities. Regardless, it appears that the arsenic is largely bound up with particulate matter and is not present in the dissolved form.

#### 5.3.2.2 Beryllium

Beryllium was identified by the HHRA as posing potential risk in groundwater. Beryllium forms a divalent ion only and can therefore form only a limited number of compounds. In the atmosphere it can be found as BeO, which may be removed via wet and dry deposition. In aqueous systems, it generally precipitates as BeCO₃ or Be(OH)₂. Its concentration in sediment has been observed to be much higher than its concentration in water above the sediment. Therefore, it is either precipitated or sorbed, but probably not dissolved in the aqueous phase, and it is not likely to be mobilized in solution. It sorbs strongly to soil particles as well, because it replaces other divalent ions which compete for sorption sites. Therefore, it is unlikely to be mobile in soil.

As with arsenic, beryllium is clearly sorbed to particulate matter. While several unfiltered groundwater samples contained beryllium, it was not detected in filtered samples.

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It can be concluded that beryllium is not mobile, and that its detection is most likely due to natural fluctuation.

### 5.3.2.3 Lead

Lead was identified in the HHRA as posing a potential risk in soils, and was also selected as a soils COPC in the ERA. The physical chemistry of lead, and, in turn, its fate and transport in the environment is difficult to analyze because of its variety of forms. In highly reducing conditions, Pb(0) predominates, and the insoluble Pb(s) is virtually the only form. Groundwater systems may sometimes be anaerobic and reducing, and it is possible that elemental lead exists in the deeper subsurface where it would be mostly immobile. In highly oxidizing conditions, Pb(IV) predominates, and the insoluble PbO_{2(s)} results. However, most of the surficial environments are likely to exist in moderate redox conditions where lead will be found primarily as Pb(II).

The precise form of lead in soils is affected by pH, organic content, the presence of inorganic colloids, and several other soil characteristics. It may exist as a precipitate, as a chelate, or within an organo-metallic complex. Regardless, it is likely to sorb strongly to soil particles and will not generally be transported in the aqueous phase. However, under acidic conditions (pH 4 to 6), in soils with a low organic content, significant leaching to groundwater is possible. In fact, in soft waters (without a high ionic content) of pH = 5.4, up to 500  $\mu$ g/L lead may be in the dissolved form. Natural rainwater has a pH of about 5.5, so there could be some leaching of lead after rain events large enough to induce infiltration. However, rainwater also has a carbonate content due to atmospheric carbon dioxide (pCO₂ = 10^{-3.5}). In such situations, the dissolved lead content will probably be limited by lead carbonates, PbCO₃ and Pb₂(OH)₂CO₃, especially if the pH of the water rises after contacting the soil. Furthermore, most rainwater and groundwater does contain other anions such as hydroxides, sulfates, and phosphates which will further limit dissolved lead concentration. Therefore, it is likely that lead will remain sorbed to particles, within both the vadose and saturated zones. However, lead could still be mobilized during significant surface runoff events while attached to suspended particulates.

Similarly, in air, most of the lead will be in the particulate form. Residence time is highly dependent on particle size, but much of the lead appears to be associated with large particles (>  $1\mu$ m), so lead may not be transported far. However, some organic, alkylated forms of lead may be both volatile and soluble. For example, tetramethyl lead, formed through bioalkylation in anaerobic environments, has a vapor pressure of 26.0 mmHg at  $20^{\circ}$ C. However, tetramethyl and the moderately volatile tetraethyl lead are photolyzed when exposed to sunlight to the tri- and dialkyl forms, which are less volatile and more soluble. These compounds may have the opportunity to leach into the groundwater. Eventually, however, these compounds are converted to inorganic lead. Thus, while lead may be briefly mobilized into the vapor and aqueous phases through anaerobic microbial methylation, it is ultimately returned to inorganic forms which will likely become sorbed into the solid phase. Detections in groundwater at Site P11/P13 were primarily in unfiltered samples, indicating that the lead is not dissolved. Therefore, it appears unlikely that significant quantities of lead will be mobilized from Site P11/P13.

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## 5.3.2.4 Manganese

Manganese was identified in the HHRA as being of potential risk in groundwater. Manganese can exist in the aqueous phase in four different oxidation states (+2, +3, +4, and +7). Naturally, the fate and transport depends on which form is dominant, and this is dependent on pH, Eh, etc. However, in most natural waters, Mn²⁺ is the most significant form. Divalent manganese is generally soluble, and in most environmental settings is controlled by MnCO₃. However, in oxidizing conditions manganese may end up as Mn⁴⁺, which forms insoluble MnO₂. On the other hand, in reducing conditions, manganese may precipitate out as a sulfide. Sorption to soils and sediments is often significant, depending on cation exchange capacity and soil organic content. Furthermore, sorption may not be easily reversible, particularly at low manganese concentrations. Finally, manganese and its compounds do not volatilize significantly, although they can be found in the atmosphere bound to suspended particulates.

Based on the discussion above, manganese in soil may be mostly immobile. However, in water it is very likely to be dissolved and therefore mobile. It was elevated in wells E3-P11-M01 and E3-P13-M02. From here, the manganese can be expected to move south, toward Honey Brook. Regardless, it is almost certainly naturally-occurring and not related to site activity.

#### 5.3.2.5 Zinc

Zinc was identified in the ERA as being a COPC in surface soils and surface water. It exists primarily in the +2 oxidation state in the environment. In most situations, the zinc ion  $(Zn^{2+})$  is in the hydrated form, which generally partitions to iron and manganese oxides, clay minerals, and organic matter. Like most sorption processes, the extent is dependent on environmental factors such as pH, redox potential, concentrations of ligands, etc. However, zinc can be mobilized in the aqueous phase, particularly at low pH. On the other hand, in reducing environments and in the presence of hydrogen sulfide, zinc sulfide will precipitate out, thereby limiting its mobility.

In general, zinc will sorb onto a variety of particles. In anaerobic soils, zinc sulfide will reduce its mobility. However, in aerobic soils, soluble salts such as zinc chloride and sulfate will be mobile, although its solubility may be controlled by other salts. In the atmosphere, it is present as particulate matter, some of which are small and may be transported long distances before returning to the soil and aqueous phases through wet and dry deposition. Zinc is an essential nutrient, present in all organisms. Not surprisingly, it is found in a variety of organisms in concentrations much greater than ambient. As with the other metals, while it is possible for zinc to mobilize, it is more likely to be found sorbed to solid particles. Furthermore, it is almost certainly naturally-occurring and not related to site activity.

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#### 5.4 CONCLUSIONS

The risk assessments identified the following types of contaminants that could pose concern at Site P11/P13: a few organic pesticides, PCBs, a PAH compound, and some metals. The pesticides, PCBs and the PAH compound have similar properties and may therefore exhibit similar fate and transport tendencies. In general they are immobile, sorbed to solid particles either in soils, sediments, or the aquifer matrix. However, because the soils in this area have a low organic content, these compounds may not be sorbed as strongly as they would otherwise be. Nevertheless, they will not dissolve in the aqueous phase; it is more likely that they will volatilize out slowly. Therefore, these compounds can be expected to remain immobilized until they vaporize.

Four of the metals that were detected, arsenic, beryllium, manganese, and zinc, are all probably present naturally in the soils. Their detections are mostly on the same order as the background samples. As for fate and transport, beryllium can be expected to sorb to solid particles, and be basically immobilized. Arsenic, manganese, and zinc may or may not be mobile. They all have forms that are soluble and can therefore move with groundwater. Manganese is likely to exist in a mobile form, since it was detected in filtered groundwater samples. Most of the arsenic detections, on the other hand, were in soils and sediment samples. Arsenic is therefore probably not present in a mobile form. However, it may be transformed chemically or biologically to a soluble, mobile species. If so, it will travel with the groundwater toward Honey Brook. Zinc is more likely to be sorbed, but could also migrate in the aqueous phase. As stated above and elsewhere in this report, these metals probably exist naturally and are not related to site activity.

Lead could be the result of on-site contamination. It is sometimes associated with petroleum hydrocarbons, which were also detected on-site. However, it is almost certainly sorbed to solid particles, whether in the soils, sediments, or aqueous phases.

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### 6. HUMAN HEALTH RISK ASSESSMENT

General Volume I, Section 4 of the RI report describes the general risk assessment approach used and contains general information relevant to the human health risk assessments for both RI sites. This site-specific risk assessment for Site P11/P13 includes additional site-specific information and presents a quantitative assessment of the potential human health risks from site-related contaminants.

This risk assessment is organized as follows:

- Section 6.1 provides an overview of Site P11/P13 and describes the conceptual site model;
- Section 6.2 summarizes the chemicals detected at the site and identifies COPCs;
- Section 6.3 assesses the potential exposure of receptors to COPCs.
   Potential exposure pathways are reviewed and exposure estimates derived, taking into account the site setting and other site characteristics;
- Section 6.4 refers to the toxicity section presented in Section 4.3 in Volume I which reviews toxicity assessment methodologies and presents brief toxicological summaries and quantitative indices of toxicity for COPCs; and
- Section 6.5 integrates the exposure estimates from Section 6.3 with toxicity indices from General Volume I, Section 4.3 to obtain quantitative risk estimates. Significant risks associated with the site are identified, along with the pathways and chemicals giving rise to these risks.

For ease of comparison, tables and figures referenced in the text are collected at the end of Section 6.

#### 6.1 INTRODUCTION

#### 6.1.1 Overview

Site P11/P13, which is located in the northern section of the Annex, was originally used by the Army from 1952 to 1957 for ordnance research and development. From 1957 to 1982, Building T405 was the center of laboratory work at P11/P13 which included research

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on foamed plastics, organic chemical synthesis, herbicides, and pesticides; flame testing; and meteorological research. Other buildings on the site were used for storage, housing, and other support services including a gas station at Building T410. Beginning in 1969, the site was also used for training of units from the Massachusetts State Police, the Air National Guard, and the Massachusetts Fire Fighting Academy (MFFA). The MFFA has used Site P13 on a limited basis from 1982. Several buildings were used for classroom instruction and equipment storage until 1988. Car fire training and flammable liquid fire training (using a burn pan apparatus and fire extinguishers) were conducted in the parking area at the north end of Site P13 until at least the fall of 1991. The site is no longer active. As a result of past activities at Site P11/P13, soils are contaminated with metals, pesticides, and other organic chemicals.

While unauthorized personnel and visitors are prohibited from entering the Annex, trespassing is known to occur. The residences nearest Site P11/P13 are located in the Towns of Maynard and Stow which are located northeast and northwest of the Annex. The Annex will eventually be released by the Army and could be developed for recreational or residential use in the future.

Detailed descriptions of the site and the nature and extent of contamination are provided in previous sections of this report.

# 6.1.2 Conceptual Site Model

A conceptual site model for Site P11/P13 is presented on Figure 6-1. As shown on the figure, there are two main exposure pathways under both existing and possible future site conditions.

- Direct contact (dermal contact and incidental ingestion) with contaminated surface soils;
- Direct contact with contaminated sediment and surface water in nearby drainage pathways and streams.

Potential receptors under current site conditions include workers who patrol the Annex, recreational users of nearby areas, and unauthorized site visitors, possibly trespassers from nearby residential areas, who might occasionally pass through or near the site. The intermittent streams adjacent to the site are not used recreationally and casual contact with sediments and surface water is expected to occur even less frequently than contact with soil. Because the chemical concentrations detected in surface water were much lower than the levels found in sediment, and because surface water and sediment exposures would occur concurrently, potential human exposures through surface water contact are regarded as minor compared to sediment exposures. Direct contact with contaminants in subsurface soil and groundwater can not occur under current conditions, however, some contaminants might eventually migrate in groundwater to the streams.

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If the site were converted to residential use following installation closure, the existing soil, sediment, and surface water pathways would also apply to future residents. If residential construction involved soil excavation, which might bring subsurface soil contaminants to the surface, future site residents could potentially be exposed to both subsurface and surface soil contamination. Groundwater in the vicinity of the site is not currently used as a water supply source, and it is not expected to be used for that purpose in the future. However, if future residents installed private wells on or downgradient of the site, they could potentially be exposed to additional contamination through domestic use of the groundwater.

### 6.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

#### 6.2.1 Data Collection

The RI investigative activities at Site P11/P13 are described in Section 2. Environmental samples collected for chemical analyses included: two rounds of groundwater samples from 10 monitoring wells and sediment and surface water samples from nine locations downgradient of the site. The analytical results for the RI samples are tabulated in Section 4.

The RI data were supplemented with data from an earlier SI by OHM (OHM 1994) to provide more complete characterization of contamination at the site. Environmental samples collected for the SI included: surface soil samples from 15 locations, subsurface soil samples from seven locations, and two rounds of groundwater samples from four monitoring wells. Both RI and SI data were used to select COPCs for the various environmental media.

## 6.2.2 Summary of Analytical Results and Chemicals of Potential Concern

The chemicals identified in the various environmental media sampled for the SI and RI at AOC 27 are summarized in Tables 6-1 through 6-7 as follows:

- Surface soil (see Table 6-1);
- Subsurface soil (see Table 6-2);
- Sediment (see Table 6-3);
- Surface water (see Table 6-4);
- Groundwater sampled by E & E, unfiltered (see Table 6-5);
- Groundwater sampled by E & E, filtered (see Table 6-6); and
- Groundwater sampled by OHM (see Table 6-7).

The tables present the frequency of detection and the range of concentrations detected for each chemical identified. For metals and pesticides, which were measured in local

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background samples, the tables also list the local background screening concentrations (see Appendix J) and the frequency with which concentrations exceeding background were detected.

As explained in the general approach, all other chemicals detected in environmental media at the site were included as COPCs, unless they were attributed to laboratory or sampling contamination. Generally, metals and pesticides that were detected at concentrations exceeding background screening criteria were also included as COPCs; however, a few that exceeded the criteria only slightly and infrequently were omitted. These are discussed below.

Table 6-8 summarizes the COPCs identified in all environmental media sampled at Site P11/P13.

### 6.2.2.1 Soils (Tables 6-1 and 6-2)

Table 6-1 summarizes the data for surface soil samples collected by OHM from former drum and aboveground storage tank locations and from the former fire training area. Table 6-2 summarizes the data for subsurface soil samples collected from former underground storage tank locations and monitoring well borings. The maximum concentrations of all metals detected in site surface soils, except beryllium, exceed local soil background values. Metals concentrations found in subsurface soil samples are similar or lower than surface soil concentrations. Arsenic only slightly exceeds the local background level and in just one surface soil sample, which probably reflects the natural variability of the soil and not contamination; therefore, arsenic is not regarded as a COPC. Generally, the highest metal concentrations were detected at the fire training area in the parking lot and at a former tank location on the east side of Building T406.

Pesticides were detected in a number of surface soil samples at concentrations exceeding background levels and were, therefore, selected as COPCs; the highest concentrations were found just east of Building T406. Other soil COPCs, which were detected in only one or two samples, include PCBs (mainly east of Building T406), semivolatile organic chemicals (at the fire training area), and volatile organic chemicals (found in trace amounts at various locations). Subsurface soils were found to be less contaminated; the only organic chemicals detected were TPHCs and a trace of toluene.

### **6.2.2.2** Sediment (Table 6-3)

Table 6-3 summarizes data for eight sediment samples: seven samples collected from the intermittent streams that carry surface drainage from the site southward to Honey Brook, and one sample collected from a groundwater seep northwest of the site on the other side of White Pond Road. A ninth sediment sample which was collected from a location in Honey Brook over 2,000 feet from the site (E3-P11-D03) was not included because that location is also downgradient of several other sites (Sites P4, P20, and P26).

The maximum detected concentrations of most metals are elevated in comparison to the local stream sediment background values; therefore, they were identified as COPCs.

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Except for aluminum, antimony, and arsenic, the highest metals concentrations in sediments were found at locations E3-P13-D01 and E3-P13-D03 at the southeast corner of the site. Antimony was detected only once, in the sample from the groundwater seep (location E3-P11-D04) collected in April 1994; antimony was not detected in the earlier December 1993 sample collected from the same location. Although the arsenic concentrations of most sediment samples exceed stream sediment background values, all but one are comparable to arsenic levels found in site soil and local background soil. The maximum arsenic concentration,  $37 \mu g/g$ , was found at location E3-P13-D04 almost 1,000 feet south of the boundary of Site P11/P13 and adjacent to Site P26; the location suggests that this elevated arsenic concentration, which is over three times the maximum detected in site soils, is not related to Site P11/P13.

Pesticides DDD, DDE, and DDT were detected in most sediment samples at concentrations exceeding local background levels, with the highest concentrations near the southeast corner of the site. Other sediment COPCs include PAHs, which were detected only once at location E3-P13-D05 approximately 1,000 feet south of the site, and TPHCs.

## 6.2.2.3 Surface Water (Table 6-4)

Table 6-4 summarizes surface water data, and compares the metals and pesticides data with local stream surface water background values. The following COPCs were detected in at least one surface water sample at concentrations exceeding local background values for surface water: aluminum, arsenic, barium, beryllium, calcium, iron, lead, magnesium, manganese, potassium, silver, vanadium, zinc, DDE, and DDT. Almost all of these chemicals were also identified as COPCs in sediment. Acetone, which was detected just once, in one of a pair of duplicate surface water samples, at a concentration near the detection limit is not considered to be a COPC.

## 6.2.2.4 Groundwater (Tables 6-5, 6-6, and 6-7)

The analytical results for unfiltered groundwater samples collected by E & E for the RI are summarized in Table 6-5. Two rounds of samples were collected from most of the ten wells sampled for the RI; however, well EHA3 was sampled only during the second round. Background values used for screening are the maximum concentrations that were found in the upgradient well, E3-P13-M03. The maximum concentrations of all metals detected in unfiltered groundwater samples from site monitoring wells exceed the concentrations found in the background well; therefore, they have been selected as COPCs. The concentration of TPHCs detected in one site groundwater sample exceeds the background level; therefore, TPHCs are also considered to be a COPC. Although bis(2-ethylhexyl)phthalate, and pesticides beta-BHC, delta-BHC, and endosulfan were detected in groundwater, the levels were not elevated in comparison with the background sample data.

The metals data for filtered groundwater samples collected from the same site monitoring wells are summarized in Table 6-6. Fewer filtered samples were collected. The maximum detected concentrations of some metals were substantially lower in filtered groundwater than in unfiltered groundwater samples and a number of metals that appear to be

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elevated in unfiltered groundwater (antimony, beryllium, iron, lead, and nickel) were not detected at all in the filtered groundwater samples. Direct comparison of the data from each filtered sample to the data from the corresponding unfiltered sample confirms that a substantial portion of the high concentrations of some metals detected in unfiltered samples are not dissolved in the groundwater, but are associated with suspended sediment.

Metals associated with suspended soil minerals are generally not mobile in groundwater and would not pose a health risk unless the water from these monitoring wells was used directly as a drinking water source. However, drinking water would not contain the high levels of sediments that have been found in the monitoring wells because drinking water supply wells are usually developed until suspended sediments are virtually eliminated. Nevertheless, EPA Region 1 has directed that the selection of groundwater COPCs and exposure estimates must be based on data from unfiltered groundwater. The use of unfiltered groundwater data to characterize contamination substantially overestimates the extent of metal contamination in the groundwater, and most likely any realistic potential human health risks. Therefore, for comparison, alternate exposure and risk estimates based on the filtered groundwater data also are presented in this risk assessment.

Table 6-7 summarizes groundwater data collected by OHM for a previous SI at Site P11. Two rounds of samples were collected from four monitoring wells (three of these wells were also sampled for the E & E RI). The OHM groundwater samples were filtered for metals analyses. All other analyses were performed on unfiltered groundwater. Table 6-7 compares the analytical results to the appropriate (filtered or unfiltered) E & E groundwater background values. Toluene and several pesticides that were detected in unfiltered groundwater at concentrations exceeding their respective background levels were added to the list of groundwater COPCs. As explained above the filtered groundwater metals data was not used to select COPCs; however, this data was used in combination with the E & E filtered groundwater data to estimate dissolved metals concentrations for the quantitative exposure and risk assessments (see Section 6.3.3.1).

### **6.3 EXPOSURE ASSESSMENT**

This section includes only site-specific information pertinent to the assessment of potential human exposures to chemical contaminants at Site P11/P13. General descriptions of the exposure assessment process and the exposure setting at the Annex can be found in General Volume I, Section 4.4 of this report.

#### 6.3.1 Characterization of the Exposure Setting

### 6.3.1.1 Physical Setting

Site P11/P13, which is located in the northern section of the Annex approximately 1.000 feet from the north gate, currently consists of eight buildings on a grass-covered field. A chain-link fence surrounds most of the site. A parking area is located outside the fence at the front of the site along White Pond Road. The ground surface is gently rolling and slopes downward toward the south and eventually to Honey Brook. The flow of groundwater from

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the northeast is split by an apparent groundwater divide which runs east to west across the site. South of the divide, groundwater flows south to the adjacent wetland and to Honey Brook. North of the divide, groundwater flows northwest and discharges to a wetland area on the other side of White Pond Road. The physical setting of the site is described in detail in Section 1 of this volume.

## **6.3.1.2 Potentially Exposed Populations**

Site P11/P13 is currently inactive and there is no reason to believe that anyone visits the site on a regular basis. The intermittent streams adjacent to the site have no recreational uses. Authorized site visitors could include security personnel who may occasionally enter in the course of patrolling the Annex and Fort Devens maintenance workers, who probably enter even less frequently. The only actively used area in the immediate vicinity of Site P11/P13 is Site P26, which is located just to the south, also on White Pond Road. Site P26, the air drop zone, is used by the Army for aerial testing using remote control aircraft. On holidays and weekends, the Army also permits local residents to use this area for flying model airplanes. Though users of Site P26 are not expected to enter Site P11/P13, they could potentially pass near or through part of the site on occasion.

Unauthorized personnel are prohibited from entering the Annex, and the perimeter fence and road barriers discourage unauthorized entry. Nevertheless, trespassers can enter the Annex fairly easily by passing around road barriers or through gaps in the fence. Poachers and exploring adolescents from nearby residential areas have been known to enter the Annex in the past and are probably the most likely unauthorized visitors. Trespassing is probably less frequent at Site P11/P13, which is located over one-half mile from the nearest off-site residences, than at other sites on the Annex that are closer to residential areas. There is no evidence of regular trespassing at Site P11/P13.

Once released by the Army, the Annex, including Site P11/P13 could potentially be redeveloped for residential use. Groundwater in the vicinity of the site currently is not used, and is unlikely to be used as a water supply source in the future, because there are existing public water supply systems in the nearby towns. However, if private wells were installed by future residents they might be exposed to site-related contamination in the groundwater.

#### **6.3.2 Potential Exposure Pathways**

A schematic depiction of the potential exposure pathways at Site P11/P13 is presented on Figure 6-1, the conceptual site model.

#### 6.3.2.1 Sources and Receiving Media

As a result of past laboratory research activities, releases from drums and storage tanks, and spills during fire training activities, soils in localized areas of Site P11/P13 were apparently contaminated with metals, pesticides, and other organic chemicals. Pesticide contamination may also be attributable in part to past widespread application of pesticides for insect control at the Annex.

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## **6.3.2.2** Contaminant Fate and Transport

The soils beneath Site P11/P13 are permeable and well-drained. As a result, precipitation tends to infiltrate carrying soluble contaminants to shallow groundwater which discharges either to the wetland northeast of the site or to the intermittent stream south of site. Surface runoff from heavy precipitation flows south, potentially carrying contaminated surface soil particles to the intermittent stream. It is unlikely that contaminants from the site would reach the larger surface water bodies downstream (Honey Brook, Taylor Brook, and the Assabet River) in sufficient quantity to pose significant risks to human health.

Volatile organic chemicals, which were detected at trace levels in site soil, have moderate-to-high solubilities. Volatiles that do not evaporate can leach to groundwater, then potentially migrate with groundwater to the wetlands surrounding the site; however, many of these chemicals degrade over time.

Many semivolatile organic chemicals, PCBs, and pesticides have low water solubilities and a tendency to bind to organic carbon in soils and sediments; therefore, migration occurs primarily by transport of particles to which these chemicals are bound. PCBs and some pesticides, including DDD, DDE, and DDT, degrade very slowly and can accumulate in aquatic organisms.

Metals are generally insoluble and relatively immobile at the normal range of pH values; however, a metal's mobility also depends on the chemical forms present, and on soil characteristics such as clay and organic carbon content. Several metals were detected at higher concentrations in sediment than in site soil, possibly due to the higher organic carbon content of the sediment samples; this appears to be true in the cases of beryllium and selenium. Metals are persistent in the environment and some, such as arsenic and selenium, can bioconcentrate in aquatic organisms.

### **6.3.2.3** Complete Exposure Pathways

As shown on Figure 6-1, the following exposure pathways are potentially complete under existing site conditions:

- Direct contact (dermal contact and incidental ingestion) with contaminated surface soils by site visitors;
- Direct contact with nearby surface water and sediments by site visitors.

If the site was converted to residential use in the future, future site residents could potentially be exposed to soil, sediment, and surface water contaminants by the same pathways as current site visitors; however, they might also be exposed to soil contamination currently in the subsurface, since excavation for construction could bring subsurface soils to the surface. Use of site groundwater by future residents is unlikely, because there are existing public water supply systems in the surrounding communities. However, if future

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residents use on-site wells for their domestic water supply, they could potentially be exposed to additional contamination in groundwater through:

- Ingestion of drinking water;
- Dermal contact while bathing or showering; and
- Inhalation of volatile contaminants.

Table 6-9 summarizes potentially complete exposure pathways and receptors. The pathways and receptors selected for quantitative evaluation are identified along with the reasons for selection or exclusion of each of the pathways.

Most of the pathways described above were quantitatively evaluated for the receptor group with the greatest expected exposure. Because the COPC concentrations detected in surface water were much lower than those found in sediment, risks from potential surface water exposures are likely to be minimal compared to potential sediment exposures; therefore, surface water exposures were not quantitatively assessed.

For potential future groundwater use, only drinking water ingestion was evaluated quantitatively. EPA Region I currently does not recommend the quantitation of dermal contact with groundwater during domestic use; since most of the groundwater COPCs are metals, which are minimally absorbed through the skin, this exposure route is not likely to be significant. Inhalation exposure is also unlikely to be significant because volatile groundwater contamination is limited to toluene which was detected in one well. Risks from inhalation of toluene released from the groundwater are discussed qualitatively in Section 6.5.2.2.

#### **6.3.3** Quantification of Exposure

This section describes how quantitative exposure estimates were obtained. The first part describes how exposure point concentrations were selected or derived. The second part presents the exposure estimate calculations for each receptor and each route of exposure, and explains the rationale for selecting the exposure factors used in the calculations.

### **6.3.3.1** Exposure Point Concentrations

The exposure media of concern at Site P11/P13 are current surface soil, future surface soil, sediment, and groundwater. Exposure point concentrations in each medium were determined directly from measured concentrations in that medium as described below. As explained in the risk assessment approach section, the maximum observed concentration and the average concentration were used to estimate exposure point concentrations for the reasonable maximum exposure (RME) and average exposure cases, respectively, in accordance with EPA Region I guidance (USEPA 1989c).

Exposure point concentrations for direct contact with surface soil were estimated from the surface soil data collected by OHM for their SIs at Sites P11 and P13 (OHM 1994). The

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soil concentrations used are listed in Table 6-10 and full data tables for positive hits are incorporated in Appendix M.

Future site development for residential use could involve excavation of soil anywhere on the site which could bring subsurface contaminants to the surface. Since all of the subsurface soil samples collected by OHM from Sites P11 and P13 were from depths of 10 feet or less, the subsurface soil data were combined with the surface soil data to estimate the future surface soil contaminant concentrations. These are listed in Table 6-11.

Exposure point concentrations for sediment contact were estimated using the sediment data for the eight locations downgradient of the site described earlier in Section 6.2.2.2. Sediment COPC exposure point concentrations are listed in Table 6-12.

Future groundwater exposures were evaluated using data from all site monitoring wells except the background well (E3-P13-M03). For metals in groundwater, exposure point concentrations were estimated separately for filtered and unfiltered groundwater using the data from both of the site groundwater investigations conducted by OHM (1994) and E & E; up to four rounds of samples were collected from each of 10 wells. For the RME case, the exposure point concentration of each COPC was the maximum concentration detected in any well over all sampling rounds. For the average case, the average COPC concentration found in the wells was used. To calculate the overall well average, multiple round averages were first calculated for each well, then the average well concentrations were averaged together. Organic chemicals detected in unfiltered groundwater samples were assumed to be dissolved and, therefore, also present in filtered groundwater. Tables 6-13 and 6-14 present the exposure point concentration estimates for unfiltered groundwater and filtered groundwater, respectively.

### **6.3.3.2** Exposure Estimation

As explained previously, two exposure scenarios were selected for the quantitative risk assessment: a current site visitor scenario and a future residential scenario. The equations used to estimate the exposure for each route of exposure are provided in Tables 6-15 through 6-21. The exposure factor values used in the calculations are also provided along with the rationale for their selection and a reference source. In accordance with EPA Region I Guidance (USEPA 1989c), the same exposure factor values were used for both the RME and average case.

For Pathway 1A, all of the exposure factors will be described and values discussed in the text. For subsequent pathways, the discussion will focus on the exposure factors and values that have not already been explained.

### Scenario 1: Exposures of Site Visitors

Site visitors could include several groups: Fort Devens security and maintenance workers who occasionally visit the site in the course of their duties, authorized personnel and visitors at nearby sites who may incidentally pass through or near the site, and Annex

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trespassers who include both adults (possibly poachers) and adolescents from nearby residential areas. Most of these receptors would be expected to visit the site infrequently and briefly, having minimal contact with contaminated soil and sediment. The receptor group with the greatest potential exposures are trespassers who might intentionally enter and spend longer periods, perhaps hours, on the site. These are most likely to be adolescents from nearby residential areas exploring around the buildings or playing in the area.

Site P11/P13 is located over one-half mile from the nearest residential area, which is outside the installation boundary in the town of Maynard. Unauthorized entry to the Annex is discouraged by the perimeter fence and roadblocks, as well as periodic security patrols. There is no evidence of regular trespassing on the site and the intermittent streams near the site have no recreational use. The average frequency at which an individual trespasses onto the site is probably no more than a few times per year. In addition, it is unlikely that a trespasser would visit Site P11/P13 (or any other area) exclusively. Exposure to soil and sediment were evaluated separately using most of the same exposure factors except for exposure frequency; sediment exposures were assumed to occur less frequently than soil exposures. The exposure factors selected for visitors are thought to be credible but conservative.

## Pathways 1A and 1C—Ingestion of Chemicals in Surface Soil and Sediment (Table 6-15)

The contaminant concentrations in soil (CS) are the average and maximum concentrations detected. The soil ingestion rate is the amount of soil or sediment that an individual might ingest through hand-to-mouth contact; the value used is EPA's standard default assumption for receptors more than 6 years old (USEPA 1991a). The relative absorption factor (RAF) accounts for the differing bioavailability between the contaminant in soil and in the administered medium (e.g., food, water) that is the basis for the toxicological index; default values are taken from EPA Region I Guidance (USEPA 1989c). The RAF values used are summarized in Table 6-22.

The fraction ingested (FI) is the fraction of soil or sediment that comes from the contaminated area of interest; this value was assumed to be 0.5 with the remainder coming from other areas. The exposure frequency is assumed to be 10 days per year for soil (less than once a week during the summer) and half as much for sediment. The exposure duration (ED), assuming adolescence lasts from ages six though 17, is 12 years.

The body weight (BW) used is the average reported for the age group (USEPA 1989d). The averaging time (AT) is the period over which the estimated exposure is averaged. For noncarcinogens, the averaging time is equal to the exposure duration, while for carcinogens it is taken as the standard life expectancy of 70 years, because the carcinogenic potency slope factors (described in Volume I, Section 5.3.3.2) are based on lifetime exposure.

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# Pathways 1B and 1D—Dermal Contact with Surface Soil and Sediment (Table 6-16)

The absorption factor (ABS) is the fraction of chemical absorbed from soil or sediment through the skin. Currently, absorption values are available for only two of the COPCs identified in soil at P11/P13, cadmium and PCBs; therefore, those are the only chemicals that will be evaluated for the dermal route. The values shown are taken from EPA Dermal Exposure Assessment Guidance (USEPA 1992d). The skin area (SA), which is the area of exposed skin which might contact soil, is estimated to be 25 percent of an individual's total body surface area based on EPA's recommendations in its dermal guidance (USEPA 1992d) and is approximately equivalent to the combined surface areas of the head, the hands, one-half the arms, and one-half the legs. The adherence factor is an estimate of the amount of soil that might cling to the skin and serve as a source of exposure. The fraction of contacted soil and sediment from the contaminated area of interest (FC), like the fraction ingested, is assumed to be half of the amount contacted.

## Scenario 2: Future Residential Exposure

Two groups of receptors (adults exposed for 30 years, and children less than six years old) were considered for the soil and groundwater exposure pathways evaluated for residential exposures. The child receptor was used to evaluate potential risks from subchronic exposures of this potentially sensitive age group, which might otherwise be "diluted" and be overlooked if only a 30-year exposure was considered.

Receptors potentially exposed to stream and wetland sediments were assumed to be adolescents from six through 17 years old. Adolescent site residents of this age are more likely than adults or small children to wander from their homes and to play in nearby streams, particularly during the warmer months of the year.

## Pathway 2A—Ingestion of Chemicals in Surface Soil (Table 6-17)

The ingestion rates (IR) used are EPA's standard default soil ingestion values for receptors more than six years old and receptors less than six years old (USEPA 1991a); the default values account for ingestion of both outdoor soil and indoor dust. The fraction ingested (FI) is assumed to be 1.0 because some adults and small children would be expected to spend all or most of their time at home. The exposure frequency (EF) is also an EPA default value, which represents year-round exposure allowing for two weeks of the year spent away from the area. Although snow cover may prevent contact with outdoor soil for part of the year, contact with contamination in indoor dust, which could approach levels in outdoor soil, occurs year-round. The exposure duration (ED) for young children is six years; for adults, ED is assumed to be 30 years, the 90th percentile length of time living at one residence. The body weight (BW) for adults and children are EPA standard default values (USEPA 1991a).

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## Pathway 2B—Dermal Contact with Surface Soil (Table 6-18)

The skin area (SA) used for adults is estimated to be 25 percent of an individual's total body surface area, based on EPA's recommendations in its Dermal Guidance (USEPA 1992d) and is approximately equivalent to the combined surface areas of the head, the hands, one-half the arms, and one-half the legs. For children, the same body parts are assumed to be exposed; the SA value is 40 percent of the total skin surface area reported for children two to six years old (USEPA 1992d).

## Pathway 2C—Ingestion of Chemicals in Sediment (Table 6-19)

The receptor most likely to have contact with sediment is assumed to be an adolescent from ages six through 17. Except for the exposure frequency (EF), the exposure factors used are identical to those assumed for adolescent site visitors under current conditions. The EF for the future resident's exposure to sediment is assumed to be 100 days per year, approximately equivalent to every day of the summer, this frequency is reasonable for an adolescent who lives on the site, close to the stream and wetland areas. The fraction ingested (FI) from contaminated sediment is assumed to be one-half of the total ingested soil and sediment; the remainder could come from other areas, including on-site soil.

# Pathway 2D—Dermal Contact with Chemicals in Sediment (Table 6-20)

As with the sediment ingestion route above, the exposure factors are identical to those used for current adolescent trespassers except for the EF, which is assumed to be 100 days per year.

# Pathway 2E—Ingestion of Chemicals in Drinking Water (Table 6-21)

The contaminant concentrations in groundwater (CW) are the average and maximum concentrations detected (see Section 6.3.3.1 above). The ingestion rates (IR) for adults and children are default values recommended for daily tap water consumption (USEPA 1989d).

### 6.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to compile toxicity data for the COPCs at the site, and to provide an estimate of the relationship between the extent of exposure to a contaminant and the likelihood and/or severity of adverse health effects. Because many of the COPCs identified at Site P11/P13 were also identified at Site A12/P36/P37. A single toxicity assessment was prepared for both sites. The toxicity assessment, which also describes toxicity assessment methodologies, is presented in Section 4.3 of Volume I.

#### 6.5 RISK CHARACTERIZATION

This section presents the quantitative estimates of potential human health risks posed by site-related contaminants at Site P11/P13 for RME and average exposure cases, and compares those estimates with risk levels deemed acceptable by EPA. The RME cases use

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the maximum observed COPC concentrations to estimate exposures, while the average cases use average concentrations. A general description of the methods used to calculate cancer risks and noncancer hazard indices are described in General Volume I, Section 4.5 of this report. Risk assessment uncertainties are discussed in General Volume I, Section 4.6.

#### 6.5.1 Risk Estimates

Detailed tables containing estimates of exposures and associated risks for the scenarios described in Section 6.3.3 are presented in Appendix O. Subchronic RfDs were used to calculate hazard indices (HIs) for receptors with exposure durations less than seven years (children), whereas chronic RfDs were used for those with EDs greater than seven years. A directory has been included in the appendix to assist the reader in locating the exposure and risk estimates for specific exposure pathways, receptors, etc. (see Appendix O). Tables 6-23 and 6-24 summarize the total cancer risks and noncancer hazard indices from the tables in Appendix O. These tables also show which exposure pathways are most responsible for the estimated risks.

### 6.5.2 Magnitude and Sources of Risks Posed by Site Contaminants

Under the current EPA Superfund policy (USEPA 1992b), acceptable exposures to carcinogens are those that represent an excess upper bound lifetime cancer risk of between 10⁻⁴ to 10⁻⁶. For noncarcinogenic effects acceptable exposures levels are those with an HI of 1.0 or less.

## 6.5.2.1 Current Risks

The estimated potential cancer risks for RMEs to contaminants at Site P11/P13 (see Table 6-23) are 4.4 x 10⁻⁷, for the adolescent site trespasser's exposure to soil and 1.8 x 10⁻⁷, for the adolescent trespasser's exposure to sediment. These are below the 10⁻⁴ to 10⁻⁶ range. The RME case assumes that all of a receptor's exposure is to the maximum contaminant concentrations observed at the site. For soil, the cancer risk associated with average exposure generally are approximately one tenth the RME risks. Cancer risks associated with average exposures to sediment are less than one-quarter the RME risks.

Both the soil and sediment exposure pathways could reasonably apply to the same site trespassers. Therefore, the estimated risks from soil and sediment contact should be summed to estimate the total receptor risk. Combining the RME risk estimates from these two pathways results in total estimated cancer risks of 6 x  $10^{-7}$  still below the  $10^{-6}$  level.

HIs for potential reasonable maximum exposures to noncarcinogenic COPCs in soil and sediment are well below EPA's benchmark value of 1.0. The total HIs of trespassers from soil and sediment contact pathways together are also well below 1.0, indicating that the occurrence of adverse noncarcinogenic health effects as a result of exposure to site-related chemicals is highly unlikely under existing site conditions.

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# 6.5.2.2 Future Risks

Under a possible future residential scenario, the estimated potential cancer risks from RMEs to site soil contamination are  $6.6 \times 10^{-5}$  for adult residents and  $4.3 \times 10^{-5}$  for children, both within the  $10^{-4}$  to  $10^{-6}$  range deemed acceptable by EPA. The estimated cancer risks for the average exposure case are lower by approximately an order of magnitude. The bulk of the estimated cancer risk is due to dermal absorption and ingestion of PCBs (98%). Noncancer HIs associated with residential RMEs to soil contaminants total 0.97 for adults and 3.6 for children; the child's HI is above the acceptable HI of 1.0. For the child, most for the estimated risk is due to dermal absorption and ingestion of PCB 1254 (HI=2.7). All other individual chemical HIs are well below 1.0.

Potential cancer risks to adolescent site residents from exposure to sediments are estimated to be  $3.6 \times 10^{-6}$  for the RME case and  $8.2 \times 10^{-7}$  for the average exposure case. Most of the estimated cancer risk (95%) is due to ingestion of arsenic. Recall that the maximum arsenic concentration which is responsible for the RME risk (37  $\mu$ g/g) was detected at sediment location E3-P13-D04 almost 1,000 feet downgradient of the site and does not appear to be site-related. Noncancer HIs associated with sediment exposures were well below 1.0, indicating that sediment contaminants are unlikely to cause adverse health effects.

Estimated potential cancer risks from consumption of unfiltered groundwater under the RME case are  $8.8 \times 10^{-4}$  for adults and  $4.1 \times 10^{-4}$  for children, above the  $10^{-4}$  to  $10^{-6}$ range. Average case risk estimates were approximately one-fifth as great. Almost all of the estimated cancer risk is due to ingestion of arsenic (90%) and beryllium (9%). However, the higher concentrations of arsenic and beryllium detected in unfiltered groundwater are associated with suspended sediments at levels that would probably not be present in groundwater actually used as drinking water (see Section 6.2.2.4). When metals data from filtered groundwater samples are used to remove the effects of suspended sediment, estimated RME cancer risks drop by two-thirds to 3.1 x 10⁻⁴ and 1.4 x 10⁻⁴ for adults and children, respectively. Again, most of the estimated cancer risk is due to arsenic (57%) and beryllium (41%); however, the estimated beryllium risks are based on a concentration equal to one-half its quantitation limit, since beryllium was not detected in any filtered groundwater samples. If beryllium is excluded from the calculation, the estimated potential cancer risks from ingestion of filtered groundwater for the RME case drop to 1.8 x 10⁻⁴ and 8.4 x 10⁻⁵ for adults and children, respectively, and the risks are mainly due to arsenic (96%), through chlordane and heptachlor epoxide also contribute to the total risk. The arsenic concentration that is responsible for these latter risk estimates is well below EPA's MCL for arsenic in drinking water of 50  $\mu$ g/L.

Total HIs for noncarcinogenic effects from consumption of groundwater based on data from unfiltered groundwater samples are 8.5 for adults and 19 for children under the RME case; HIs are approximately one-fifth as great for the average exposure case. The RME total is mostly due to arsenic (HI=8.0), manganese (HI=7.5), and antimony (HI=2.0). When the risks are recalculated using metals data from filtered groundwater samples, the total HIs for the RME case drop to 3.1 for adults and 6.7 for children. The only chemicals with HIs exceeding 1.0 are manganese (HI=3.5) and arsenic (HI=1.8). The RfDs for manganese and

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arsenic are based on different toxicity endpoints (affecting the nervous system and skin, respectively); therefore, their HIs should not be summed together but should be considered separately. Total HIs estimated for the average exposure case were less than 1.0 for both adults and children.

Potential exposures via inhalation of volatile contaminants in groundwater were not evaluated quantitatively. The only volatile COPC identified in site groundwater was toluene, which was detected in one well during OHM's investigation; the maximum detected concentration was  $34 \mu g/g$ . Toluene is not classified as a carcinogen. If the noncancer risk from inhalation of toluene was assumed to be equal to twice the risk from ingestion, as recommended by EPA Region I, the HI associated with inhalation of toluene from groundwater at the maximum detected concentration would be approximately 0.01 for adults and less for children, well below the 1.0 benchmark and the total risks from the groundwater ingestion pathway.

Because future residents could potentially be exposed to contaminants in both soil and groundwater, the risks from these media should be summed together for these receptors. Combining the estimated RME cancer risks for adult residents gives a total cancer risk of approximately  $1 \times 10^{-3}$  based on unfiltered groundwater data, or  $4 \times 10^{-4}$  based on filtered groundwater data. Most of the estimated cancer risk is associated with groundwater ingestion.

#### 6.5.3 Risks from Lead

Lead, which has no EPA-approved RfD or SF, was not included in the quantitative risk estimates. The maximum observed lead concentration at Site P11/P13 was 180 mg/kg detected in surface soil. That concentration is well below EPA's recommended screening level of 400 ppm for lead in residential soil, suggesting that serious human health effects from exposure to lead in site soil and sediment are unlikely.

Lead was also detected in unfiltered groundwater from site monitoring wells. Lead concentrations exceeding EPA's drinking water action level of 15  $\mu$ g/L were found in two of the nine wells sampled, and the maximum observed concentration was 80.2  $\mu$ g/L. However, the elevated lead concentrations appear to be associated with high levels of suspended sediments in the unfiltered samples, levels that would not be present in a well developed for drinking water use. Lead concentrations in all filtered groundwater samples were less than 5  $\mu$ g/L, confirming that the higher lead concentrations in unfiltered samples were due to suspended sediments, and indicating that lead in site groundwater does not pose a significant hazard to human health.

#### 6.5.4 Perspective on Arsenic Exposure and Risks

A major portion of the estimated risks associated with sediment and groundwater pathways evaluated at Site P11/P13 are due to potential exposure to arsenic which was detected at concentrations greater than the local background levels in sediment and groundwater. Nevertheless, the arsenic levels found in these media were only modestly elevated. Although most of the arsenic concentrations that were detected in site sediment

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exceed the local sediment background value (2.03  $\mu$ g/g), the maximum detected concentration, 37  $\mu$ g/g, which is associated with an estimated cancer risk of 3.5 x 10⁻⁶, is less than four times the local soil background level (10  $\mu$ g/g). Similarly, the maximum arsenic concentration detected in filtered site groundwater, 8.21  $\mu$ g/L, which is associated with an estimated cancer risk of 1.7 x 10⁻⁴ if present in drinking water, is only five times the level detected in the background well and less than one-fifth the current drinking water standard for arsenic. Because arsenic is naturally present in the environment, humans are exposed to arsenic in food, air, and water on a daily basis. Therefore, to put the potential site-related exposures and risks in perspective, it is important to be aware of the routine nonsite-related exposures to arsenic and the risks that could be associated with those exposures. Table 6-25 compares estimated risks from routine intake of arsenic to risks associated with potential exposures to arsenic in site sediment and groundwater.

The general population of the United States is estimated to be exposed to 25 to 50 µg of arsenic per day, primarily in food and drinking water (ATSDR 1992a; WHO 1981). For a 70-kg adult, these intake rates correspond to estimated cancer risks of 6 x 10⁻⁴ to 1 x 10⁻³ and an estimated hazard index of 1.2 to 2.4 for noncarcinogenic effects. The Federal MCL for arsenic in drinking water is 50 µg/L. Using EPA's standard default drinking water EFs, the MCL concentration would correspond to an estimated cancer risk of 2.5 x 10⁻³ and an estimated hazard index of 4.8.

#### 6.5.5 Nature of Potential Adverse Health Effects

The site contaminants estimated to pose potential excess lifetime cancer risks greater than 10⁻⁶ include arsenic, beryllium, chlordane, heptachlor epoxide, and PCBs. Arsenic is classified as a Group A, human carcinogen. Oral exposure to arsenic is known to cause skin cancer, and there is mounting evidence that ingestion of arsenic may also cause liver, kidney, bladder, or lung cancer. The others are all classified as Group B2, probable human carcinogens, based on carcinogenicity in animals. Beryllium has caused various types of tumors in exposed animals. Oral exposures to chlordane, heptachlor epoxide, and PCBs are associated with liver cancer.

Site contaminants that pose potentially significant noncarcinogenic adverse health effects via ingestion or dermal routes include arsenic, manganese, and PCBs. Overexposure to arsenic can cause damage to the kidneys and blood, weight changes, and possible keratosis and hyperpigmentation of the skin in humans. A few studies suggest that ingestion of manganese can cause changes in brain chemistry; however, reports of adverse effects in humans from ingestion of manganese are rare. In animals, PCBs have caused liver damage, skin irritations, low birth weights and other reproductive effects, immunosuppression, and death; however, the only significant adverse health effects reported in PCB-exposed workers are skin irritations and liver effects.

#### 6.5.6 Major Factors Driving Estimated Site Risks

The major factors driving estimated site risks are:

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• The presence of PCBs and pesticides in site soils and potential exposures by site trespassers and future site residents; and

• The presence of elevated concentrations of metals (primarily arsenic and manganese) in the groundwater coupled with the possible future use of groundwater as a drinking water source.

Exposures to soil contaminants are either currently occurring or could reasonably be expected under current land use conditions; however, the conservative (health protective) exposure assumptions used may overestimate actual exposures.

Groundwater in the vicinity of the site is not a current or likely future water supply source because there is an existing public water supply system. Therefore, the probability of exposure to site contaminants in groundwater is extremely small.

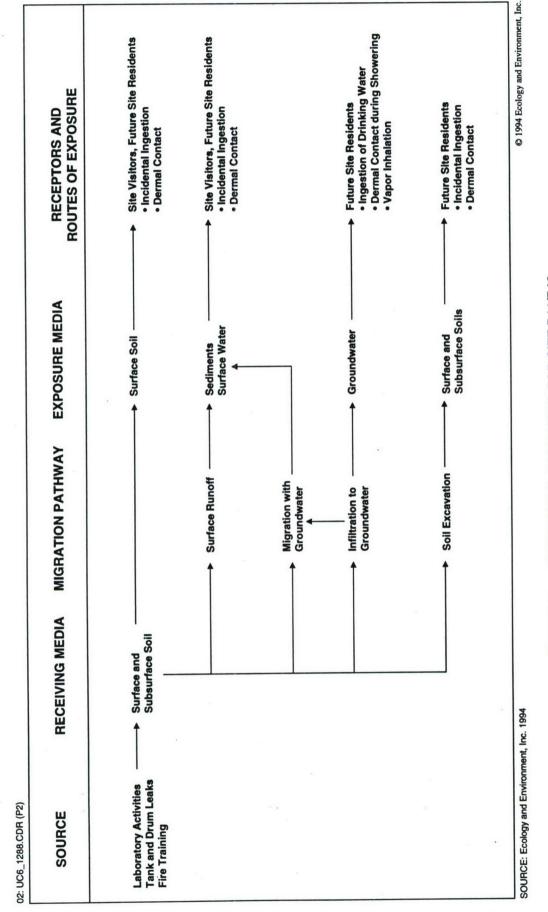


Figure 6-1 CONCEPTUAL SITE MODEL FOR SITE P11/P13

		Ra	nge			
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background	
Inorganics						
Aluminum ^b	15/15	5,800	14,000	10,400	3/15	
Arsenic	15/15	4.36	11	10	1/15	
Barium ^b	15/15	14.4	252	25.1	7/15	
Beryllium	3/15	0.317	0.427	0.446	0/15	
Cadmium ^b	15/15	0.358	14.2	0.5	14/15	
Calcium ^b	13/15	418	6,030	1,170	3/15	
Chromium ^b	15/15	8.2	42.7	14.2	10/15	
Cobalt ^b	13/15	2.65	10.7	6.1	3/15	
Copper ^b	15/15	3.42	550	10.7	11/15	
Iron ^b	15/15	7,300	24,000	12,300	3/15	
Lead ^b	15/15	24	180	150	2/15	
Magnesium ^b	15/15	599	8,260	2,310	7/15	
Manganese ^b	15/15	31.3	460	95.8	13/15	
Mercury ^b	4/15	0.094	0.426	0.318	1/15	
Nickel ^b	15/15	2.55	30.9	10.7	7/15	
Potassium ^b	15/15	263	4,340	617	12/15	
Sodium ^b	1/15	577	577	200	1/15	
Vanadium ^b	15/15	11.3	109	33.0	2/15	
Zinc ^b	14/15	21.5	910	44.6	6/15	
Pesticides/PCBs						
α-Chlordane ^b	4/15	0.0435	0.35	0.004	4/15	
γ-Chlordane ^b	4/15	0.0476	0.46	0.005	3/15	
p,p'-DDT ^b	15/15	0.0146	1.1	0.233	6/15	
p,p'-DDD ^b	3/15	0.035	0.59	0.063	2/15	
p,p'-DDE ^b	9/15	0.016 ^a	0.84	0.139	4/15	

Key at end of table.

Table 6-1 SUMMARY OF SURFICIAL SOIL ANALYTICAL RESULTS SITE P11/P13 (μg/g)

		Range				
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background	
Heptachlor ^b	1/15	0.0202	0.0202	<0.001 ^c	1/15	
Heptachlor epoxideb	4/15	0.0146	0.16	0.006	4/15	
Endosulfan, B ^b	1/15	0.29	0.29	0.004	1/15	
Dieldrin ^b	1/15	0.0413	0.0413	0.023	1/15	
PCB 1254 ^b	2/15	0.61	3.4	<0.02 ^c	2/15	
PCB 1260 ^b	1/15	0.455	0.455	<0.02 ^c	1/15	
Semivolatile Organics						
2-Methylnaphthylene ^b	1/15	2.61	2.61	-	_	
Acenaphthene ^b	1/15	0.747	0.747	-	_	
Bis(2-ethylhexyl)phthalate ^b	3/15	0.56	18.3	-	-	
Chrysene ^b	1/15	2.42	2.42	-	-	
Di-n-octyl phthalate ^b	1/15	1.49	1.49	-	-	
Phenanthreneb	1/15	2.11	2.11	I		
Pyrene ^b	1/15	3.54	3.54	ı	1	
Volatile Organics						
Methylene chloride ^b	1/15	0.014	0.014	_	_	
Methylethyl ketone ^b	1/15	0.0026 ^a	0.0026 ^a		_	
Tolueneb	2/15	0.0023	0.0039	_	_	
1,1,1-Trichloroethane ^b	2/15	0.0012 ^a	0.0016	-	_	
Trichlorofluoromethaneb	1/15	0.012	0.012	_	_	

 $[\]begin{array}{ll} a & \text{Average of duplicate samples.} \\ b & \text{Selected as a COPC.} \end{array}$ 

### Key:

- = Not analyzed/not applicable.

^C Contract reporting limit.

		Ra	nge	3	
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background
Inorganics					
Aluminum	7/7	4,550 ^a	8,800	10,400	0/7
Arsenic	7/7	3.54	9.6ª	10	0/7
Barium ^c	5/7	12.3	28.3	25.1	1/7
Beryllium	1/6	0.283	0.238	0.446	0/7
Cadmium ^c	5/7	0.586	13.1	0.5	7/7
Calcium	4/7	455 ^a	797 ^a	1,170	0/7
Chromium	7/7	8.74	13.1	14.2	0/7
Cobalt	1/6	3.29	3.29	6.1	0/7
Copper ^c	7/7	4.72 ^a	16.1	10.7	1/7
Iron ^c	7/7	6,150 ^a	16,000	12,300	1/7
Lead	7/7	2.35	5.95	150	0/7
Magnesium	7/7	1,220	2,180	2,310	0/7
Manganese ^c	7/7	55.8	120	95.8	4/7
Mercury	1/7	0.0924	0.0924	0.318	0/7
Nickel	7/7	3.84 ^a	8.49 ^a	10.7	0/7
Potassium ^c	7/7	770	2,130	617	7/7
Vanadium	7/7	8.32 ^a	16	33.0	0/7
Zinc	7/7	12.6ª	23.4	44.6	0/7
Volatile Organics					
Toluene ^c	1/10	0.0023	0.0023	_	_
Other Organics			V		
Total Petroleum Hydrocarbons ^c	1/2	13	13 ^b	-	_

## Table 6-2 (Cont.)

- a Average of duplicate samples.
  b Detected in one of two duplicate samples.
  c Selected as a COPC.

### Key:

- = Not analyzed/not applicable.

		Ra	nge		
Analyte	Detection Frequency	Minimum	Maximum	Local Stream Sediment Background	Frequency of Exceedance of Background
Inorganics					
Aluminum ^b	8/8	2,490	8,700	5,020	2/8
Antimony ^b	1/8	1.01	1.01	< 0.5	1/8
Arsenic ^b	8/8	0.941	37.0	2.03	7/8
Barium ^b	8/8	10.9	59.2	23.9	2/8
Beryllium ^b	8/8	0.062	0.632	0.18	6/8
Cadmium ^b	1/8	1.43	1.43	< 0.5	1/8
Calcium ^b	7/8	480	19,800	562	6/8
Chromium ^b	8/8	2.87	15.2	9.66	3/8
Cobalt ^b	8/8	1.39	9.9	3.74	3/8
Copper ^b	8/8	2.21	29.6	6.33	4/8
Iron ^b	8/8	3,000	76,500	7,590	2/8
Lead ^b	8/8	6.00	71.0	4.48	8/8
Magnesium	8/8	409	2,165	2,140	1/8
Manganese ^b	8/8	14.4	84.3	70.5	3/8
Nickel ^b	8/8	4.02	26.5	5.12	6/8
Potassium	5/8	311	1,060	1,520	0/8
Selenium ^b	5/8	0.537	2.30	0.2	5/8
Vanadium ^b	8/8	2.94	26.9	17	1/8
Zinc ^b	8/8	12.0	370	20.8	4/8
Pesticides					
p,p'-DDD ^b	7/8	0.008	0.725	<0.002 ^c	7/7
p,p'-DDE ^b	7/8	0.022	0.510	<0.002 ^c	7/7
p,p'-DDT ^b	5/8	0.012	0.230	<0.002 ^c	5/7

# Table 6-3 SUMMARY OF SEDIMENT ANALYTICAL RESULTS

#### SITE P11/P13 (μg/g) Range Local Stream Frequency of Sediment Exceedance of Detection Analyte Frequency Minimum **Background** Background Maximum Semivolatile Organics Benzo(b)fluorantheneb 1/8 0.082 0.082 Fluorantheneb 1/8 0.120 0.120 Pyrene^b 1/8 0.068 0.068 Other Organics 4/8 26.0 263 Total petroleum

hydrocarbonsb

#### Key

- = Not analyzed/not applicable.

a Locations E3-P11-D01, E3-P11-D02, and E3-P11-D04 (metals data from sample collected 4/26/94).

b Selected as a COPC.

^C Contract reporting limit.

Table 6-4  $SUMMARY\ OF\ SURFACE\ WATER\ ANALYTICAL\ RESULTS$   $SITE\ P11/P13\ (\mu g/L)$ 

		Ra	nge		
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background
Inorganics					
Aluminum ^c	6/6	73.0	3,500 ^b	400	4/6
Arsenic ^c	5/6	1.41	4.60	3.15	1/6
Barium ^c	6/6	7.85	65.3 ^b	10.4	4/6
Beryllium ^c	2/6	0.252 ^b	0.268	0.18	2/6
Cadmium	1/6	1.46	1.46	<5 ^d	0/6
Calcium ^c	6/6	4,690	11,200	8,520	2/6
Chromium	1/6	3.89	3.89	9.66	0/6
Cobalt	1/6	3.14 ^b	3.14 ^b	3.74	0/6
Copper	4/6	4.03	8.9b	<10 ^d	0/6
Iron ^c	6/6	220	5,100	4,810	1/6
Lead ^C	4/6	1.24	17.3 ^b	10.3	3/6
Magnesium ^c	6/6	533	2,610	1,890	1/6
Manganese ^c	6/6	24.5	530 ^b	156	1/6
Potassium ^c	2/6	2,120	6,010	2,060	2/6
Silver ^c	1/6	2.31	2.31	<2.0 ^d	1/6
Sodium	3/6	6,350	9,340	14,000	0/6
Vanadium ^c	4/6	2.84	7.9 ^b	4.72	1/6
Zinc ^c	6/6	23.9	181	13.3	6/6
Pesticides		8			
p,p'-DDD	2/7	0.016	0.018	<0.04 ^d	0/7
p,p'-DDE ^c	2/7	0.019	0.055	<0.04 ^d	1/7
p,p'-DDT ^c	1/7	0.263	0.263	<0.04 ^d	1/7
Volatile Organic Chemicals		9			ě.
Acetone	1/6	8.5 ^b	8.5 ^b	-	_

### Table 6-4 (Cont.)

- a Locations E3-P11-D01, E3-P11-D02, and E3-P-11-D04 (metals data from sample collected 4/26/94).
  b Average of duplicate samples.
  c Selected as a COPC.
  d Contract reporting limit.

— = Not analyzed/not applicable.

Table 6-5

# SUMMARY OF E & E's ANALYTICAL RESULTS FOR UNFILTERED GROUNDWATER SITE P11/P13

		(46, 2)			
		Ra	nge		
Chemical	Detection Frequency	Minimum	Maximum	Local Background (E3-P13-M03)	Frequency of Exceedance Background
Inorganics					
Aluminum ^b	17/17	122	34,000 ^a	5440	8/17
Antimony ^b	3/17	2.39	12.3	< 5	1/17
Arsenic ^b	16/17	0.83	37.5	5.99	5/17
Barium ^b	15/17	7.13	198	69.3	4/17
Beryllium ^b	8/17	0.175	1.61 ^a	0.378	6/17
Cadmium	3/17	2.06	3.45	<5	0/17
Calcium ^b	17/17	3290	28400	25550	1/17
Chromium ^b	11/17	4.86	64.4 ^a	13.3	6/17
Cobalt ^b	9/17	4.03	26.35 ^a	7.72	6/17
Copper ^b	15/17	1.54	45.35 ^a	6.55	8/17
Iron ^b	17/17	385	38000	6600	8/17
Lead ^b	8/17	3.98	80.2	3.11	8/17
Magnesium ^b	17/17	423	14200	3900	6/17
Manganese ^b	17/17	9.38	588.5ª	210	5/17
Nickel ^b	9/17	8.17	61.55 ^a	15.5	6/17
Potassium ^b	16/17	1180	10,335 ^a	4,960	3/17
Sodium	14/17	2240	42,400	42,200	1/17
Vanadium ^b	12/17	4.14	69.85 ^a	11.1	9/17
Zinc ^b	12/17	29.4	416	<27	12/17
Pesticides		values values			
beta-BHC	1/17	0.033	0.033	< 0.08	0/17
delta-BHC	3/17	0.033	0.058	< 0.08	0/17
Endosulfan, A	1/17	0.028	0.028	< 0.16	0/17

## SUMMARY OF E & E's ANALYTICAL RESULTS FOR UNFILTERED **GROUNDWATER SITE P11/P13**

		Range					
Chemical	Detection Frequency	Minimum	Maximum	Local Background (E3-P13-M03)	Frequency of Exceedance Background		
Semivolatile Organics	Semivolatile Organics						
Bis(2-ethylhexyl)phthalate	1/11	5.6	5.6	<10	0/11		
Other Organics							
Total Petroleum Hydrocarbons ^b	3/15	187	535	332	1/15		

 $[\]begin{array}{ll} a & \\ Average \ of \ duplicate \ samples. \\ b & \\ Selected \ as \ a \ COPC. \end{array}$ 

Table 6-6

# SUMMARY OF E & E's ANALYTICAL RESULTS FOR FILTERED GROUNDWATER SITE P11/P13

		Range			
Chemical	Detection Frequency	Minimum	Maximum	Local Background (E3-P13-M03)	Frequency of Exceedance Above Background
Inorganics					
Aluminum	1/15	121	121	<28.9	1/15
Arsenic	6/15	1.12	6.5	1.63	3/15
Barium	8/15	6.16	35.6	37.7	0/15
.Cadmium	2/15	1.88	2.97	<5	0/15
Calcium	15/15	2,130	29,100	24,900	1/15
Chromium	2/15	5.17	6.16	<10	0/15
Cobalt	1/15	4.62	4.62	4.68	0/15
Copper	5/15	1.52	4.21	1.57	4/15
Magnesium	15/15	205	4,240	2,180	1/15
Manganese	10/15	12.6	271	172	2/15
Potassium	13/15	596	4,980	3,800	2/15
Sodium	12/15	2,590	43,900	43,700	1/15
Vanadium	. 1/15	11.1	11.1	<10	1/15
Zinc	2/15	22.9	22.9	<21.6	2/15

		Ra	nge	8				
Chemical	Detection Frequency	Minimum	Maximum	Local Background (E3-P13-M03)	Frequency of Exceedance Above Background			
Inorganics								
Aluminum	2/8	425	1,300	<28.9	2/8			
Arsenic	2/8	4.07	8.21	1.63	2/8			
Calcium	8/8	3,270	69,000	24,900	2/8			
Chromium	1/8	23.5	23.5	<10	1/8			
Copper	2/8	10.7	21	1.57	2/8			
Iron	1/8	189	189	677	0/8			
Lead	6/8	1.42 ^b	3.74	<5	0/8			
Manganese	4/8	7.25 ^b	17	172	0/8			
Potassium	8/8	2,110	4,910	3,800	3/8			
Sodium	7/8	3,070	22,000	43,700	0/8			
Vanadium	2/8	24	42.4	<10	2/8			
Zinc	6/8	10.1	19.3	<21.6	0/8			
Pesticides								
p,p'-DDT ^c	1/8	0.07	0.07	< 0.04	1/8			
Endrin ^c	1/8	0.043	0.043	< 0.04	1/8			
Heptachlor epoxide ^c	1/8	0.026	0.026	< 0.02	1/8			
α-Chlordane ^c	1/8	0.261	0.261	<0.1	1/8			
Endosulfan, B	1/8	0.022	0.022	< 0.04	0/8			
Semivolatile Organics								
Bis(2-ethylhexyl)phthalate	1/8	7.3	7.3	<10	0/8			
Volatile Organics								
Methylene chloride	3/8	5.6	6.3	<7.8	0/8			
Toluene ^c	2/8	6.6	34	. 5	2/8			

## Table 6-7 (Cont.)

Source: OHM 1994.

 $f{a}$  Samples were filtered for metals analysis. All other analyses were performed on unfiltered samples.  $f{b}$  Average of duplicate samples.  $f{c}$  Selected as a COPC.

Table 6-8

CHEMICALS OF POTENTIAL CONCERN SITE P11/P13

Chemical	Surface Soil	Subsurface Soil	Sediment	Surface Water	Groundwater
Metals					
Aluminum	X		х	х	х
Antimony			х		х
Arsenic			х	х	х
Barium	х	х	Х	х	х
Beryllium			Х	X	х
Cadmium	х	х	х		
Calcium	х		х	x	х
Chromium	х		х		х
Cobalt	х		Х		х
Copper	х	х	х		х
Iron	х	х	х	х	х
Lead	х		Х	х	. X
Magnesium	х			X	Х .
Manganese	X	х	х	х	х
Mercury	х				
Nickel	х		х		х
Potassium	х	х		x	х
Selenium			х		
Silver				X	
Sodium	х		.8		
Vanadium	х		х	x	х
Zinc	х	х	х	Х	х
Pesticides/PCBs					١
alpha-Chlordane	х				х
gamma-Chlordane	х				
p,p'-DDD	X		х		
p,p'-DDE	х		X	х	

Table 6-8

## CHEMICALS OF POTENTIAL CONCERN SITE P11/P13

Chemical	Surface Soil	Subsurface Soil	Sediment	Surface Water	Groundwater
p,p'-DDT	х		х	х	Х
Dieldrin	х				
Endosulfan, B	Х				
Endrin					Х
Heptachlor	X				
Heptachlor epoxide	X				Х
PCB 1254	X				
PCB 1260	X				
Semivolatile Organics					
Bis(2-ethylhexyl)phthalate	х				,
Di-n-octylphthalate	X				
Acenaphthene	X				
Benzo(b)fluoranthene			х		
Chrysene	X				
Fluoranthene			х		
2-Methylnaphthylene	X				
Phenanthrene	Х				
Pyrene	X		х		
Volatile Organics					
Methylene chloride	X				
Methyl ethyl ketone	X			*	
1,1,1-Trichloroethane	Х				
Toluene	X	х			Х
Trichlorofluoromethane	Х				
Other Organics			,		
Total petroleum hydrocarbons	X		X		x

### Table 6-8 (Cont.)

Note: Groundwater COPC selection is based on unfiltered groundwater data.

Key:

E = Elevated above sediment background levels but not soil background levels.

X = Selected as a COPC for the human health risk assessment.

Table 6-9

# POTENTIAL HUMAN EXPOSURE PATHWAYS SITE P11/P13

Potentially Exposed Population	Exposure Routes, Medium, and Exposure Points	Pathway Selected for Evaluation	Reason for Selection or Exclusion
Current Land Use			
Site visitors (trespassers)	Dermal absorption and ingestion of COPCs in site soil	Yes	COPCs ^a have been found in site soil. Trespassing may occur.
,	Dermal absorption and ingestion of COPCs in sediment	Yes	COPCs have been found in nearby stream sediment.
	Dermal absorption and ingestion of COPCs in surface water	No	Surface water COPC levels are much lower than those detected in sediment. Potential exposures are minimal in comparison.
Future Land Use	*		
Future site residents	Dermal absorption and ingestion of COPCs in site soil.	Yes	COPCs have been found in site soil.
	Dermal absorption and ingestion of COPCs in sediment	Yes	COPCs have been found in nearby stream sediment.
	Dermal absorption and ingestion of COPCs in surface water	No	Surface water COPC levels are much lower than those detected in sediment. Potential exposures are minimal in comparison.
٨	Use of groundwater as residential drinking water.	Yes	Future residents could install private wells on site or downgradient.
,	Dermal contact while bathing or showering.	No	EPA Region I currently does not recommend the quantitation of dermal contact.
	Inhalation of vapors released during water usage.	No	VOCs are minor contaminants in groundwater. Risk will be discussed qualitatively.

 $^{{\}bf a}$  Chemicals of potential concern.

**Table 6-10** 

# CURRENT SURFACE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

	(μg/g)	
Chemical	Average	Maximum
Metals		
Aluminum	9,140	14,000
Barium	41.1	252
Cadmium	2.45	14.2
Calcium	1,110	6,030
Chromium ^a	17.2	42.7
Cobalt	4.11	10.7
Copper	55.8	550
Iron	12,200	24,000
Lead	72.4	180
Magnesium	2,630	8,260
Manganese	196	460
Mercury	0.080	0.426
Nickel	12.9	30.9
Potassium	1,240	4,340
Sodium	162	577
Vanadium	24.2	109
Zinc	132	910
PCBs		
PCB-1254	0.297	3.4
PCB-1260	0.092	0.455
Pesticides		
alpha-Chlordane	0.049	0.35
gamma-Chlordane	0.066	0.46
p,p'-DDD	0.063	0.59
p,p'-DDE	0.143	0.84
p,p'-DDT	0.283	1.1
Dieldrin	0.0087	0.0413
Endosulfan, B	0.023	0.29

# CURRENT SURFACE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

Chemical	Average	Maximum			
Heptachlor	0.0059	0.0202			
Heptachlor epoxide	0.0213	0.16			
Semivolatile Organics					
Bis(2-ethylhexyl)phthalate	1.94	18.3			
Di-n-butylphthalate	0.882	1.1			
Di-n-octylphthalate	0.284	1.49			
Acenaphthene	0.210	0.747			
Chrysene	0.361	2.42			
2-Methylnaphthalene	0.371	2.61			
Phenanthrene	0.299	2.11			
Pyrene	0.817	3.54			
Volatile Organics					
Methylene chloride	0.0036	0.014			
Methyl ethyl ketone	0.0020	0.0026			
Toluene	0.0011	0.0039			
1,1,1-Trichloroethane	0.0007	0.0016			
Trichlorofluoromethane	0.012	0.012			

 $^{^{\}mbox{\scriptsize a}}$  Total chromium assumed to be 90% Cr III and 10% Cr VI.

## FUTURE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

	(μg/g)	
Chemical	Average	Maximum
Metals		
Aluminum	8,110	14,000
Barium	32.6	252
Cadmium	2.73	14.2
Calcium	880	6,030
Chromium ^a	15.3	42.7
Cobalt	3.23	10.7
Copper	40.6	550
Iron	11,400	24,000
Lead	50.5	180
Magnesium	2,380	8,260
Manganese	162	460
Mercury	0.067	0.426
Nickel	10.8	30.9
Potassium	1,210	4,340
Sodium	152	577
Vanadium	20.3	109
Zinc	95.3	910
PCBs		
PCB-1254	0.209	3.4
PCB-1260	0.069	0.455
Pesticides		
alpha-Chlordane	0.034	0.35
gamma-Chlordane	0.048	0.46
p,p'-DDD	0.045	0.59
p,p'-DDE	0.100	0.84
p,p'-DDT	0.194	1.1
Dieldrin	0.0072	0.0413
Endosulfan, B	0.017	0.29

## FUTURE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

Chemical	Average	Maximum
Heptachlor	0.0055	0.0202
Heptachlor epoxide	0.0152	0.16
Semivolatile Organics		
Bis(2-ethylhexyl)phthalate1.57	1.57	18.3
Di-n-octylphthalate	0.229	1.49
Acenaphthene	0.185	0.747
Chrysene	0.264	2.42
2-Methylnaphthalene	0.269	2.61
Phenanthrene	0.217	2.11
Pyrene	0.600	3.54
Volatile Organics		
Methylene chloride	0.0033	0.014
Methyl ethyl ketone	0.0020	0.0026
Toluene	0.0010	0.0039
1,1,1-Trichloroethane	0.0007	0.0016
Trichlorofluoroethane	0.012	0.012
Other Organics		
Total petroleum hydrocarbons	13	13

 $^{^{\}rm a}$  Total chromium assumed to be 90% Cr III and 10% Cr VI.

## SEDIMENT COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

	(µg/g)			
Chemical	Average	Maximum		
Metals				
Aluminum	4,660	8,700		
Antimony	0.345	1.01		
Arsenic	8.02	37.0		
Barium	22.7	59.2		
Beryllium	0.265	0.632		
Cadmium	0.418	1.43		
Calcium	3,440	19,800		
Chromium ^a	7.58	15.2		
Cobalt	· 4.09	9.9		
Copper	10.7	29.6		
Iron	16,600	76,500		
Lead	28.5	71.0		
Magnesium	1,150	2,165		
Manganese	48.1	84.3		
Nickel	9.44	26.5		
Potassium	432	1,060		
Selenium	1.90	2.30		
Vanadium	11.4	26.9		
Zinc	94.6	370		
Pesticides				
p,p'-DDD	0.134	0.725		
p,p'-DDE	0.103	0.510		
p,p'-DDT	0.056	0.230		
Semivolatile Organics				
Benzo(b)fluoranthene	0.082	0.082		
Fluoranthene	0.120	0.120		
Pyrene	0.068	0.068		

# SEDIMENT COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

Chemical Average Maximum				
Other Organics				
Total petroleum hydrocarbons 64.3 263				

 $^{^{\}mbox{\scriptsize a}}$  Total chromium assumed to be 90% Cr III and 10% Cr VI.

### UNFILTERED GROUNDWATER COPC EXPOSURE POINT CONCENTRATIONS AT SITE P11/P13

(μg/L	'			
Chemical	Average	Maximum		
Metals				
Aluminum	8,290	34,000		
Antimony	3.03	12.3		
Arsenic	6.79	37.5		
Barium	48.5	198		
Beryllium	0.784	1.61		
Calcium	11,000	28,400		
Chromium	18.8	64.4		
Cobalt	8.7	26.4		
Copper	13.2	45.4		
Iron	9,040	38,000		
Lead	11.0	80.2		
Magnesium	3,280	14,200		
Manganese	152	588		
Nickel	15.2	61.6		
Potassium	4,150	10,300		
Vanadium	18.4	69.8		
Zinc	204	416		
Pesticides				
alpha-Chlordane	0.121	0.261		
p,p'-DDT	0.021	0.07		
Endrin	0.027	0.043		
Heptachlor epoxide	0.009	0.026		
Volatile Organics				
Toluene	2.98	34		
Other Organics				
Total Petroleum Hydrocarbons	350	535		

**Table 6-14** 

## FILTERED GROUNDWATER COPC **EXPOSURE POINT CONCENTRATIONS SITE P11/P13**

Chemical	Average	Maximum		
Metals				
Aluminum	243	1,300		
Antimony	2.5 ^b	2.5 ^a		
Arsenic	1.64	8.21		
Barium	11.3	35.6		
Beryllium	2.11 ^b	2.50 ^a		
Calcium	10,800	69,000		
Chromium	4.98	23.5		
Cobalt	7.08	4.62		
Copper	4.19	21		
Iron	42.2	189		
Lead	2.38	3.74		
Magnesium	1,040	4,240		
Manganese	48.2	271		
Nickel	7.68 ^b	15.0 ^a		
Potassium	2,540	4,980		
Vanadium	8.09	42.4		
Zinc	15.5	22.9		
Pesticides				
alpha-Chlordane	0.121	0.261		
p,p'-DDT	0.021	0.07		
Endrin	0.027	0.043		
Heptachlor epoxide	0.009	0.026		
Volatile Organics				
Toluene	2.98	34		
Other Organics				
Total Petroleum Hydrocarbons	350	535		

 $[\]begin{array}{lll} a & \text{Value equals one-half the maximum quantitation limit used.} \\ b & \text{Value equals one-half the average quantitation limit used.} \end{array}$ 

# SITE P11/P13 TRESPASSER EXPOSURE:

# PATHWAYS 1A AND 1C - INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL AND SEDIMENT

(ADOLESCENT SITE VISITORS)

Equation:

Intake  $(mg/kg-day) = \frac{CS \times IR \times RAF \times CF \times FI \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/soil/day)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10⁻⁶ kg/mg)

FI = Fraction Ingested from Contaminated Source (unitless)

EF = Exposure Frequency (day/years) ED = Exposure Duration (years) BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
cs	Adolescent	Average	Average concentration in surface soil or sediment.
		RME	Maximum observed concentration in surface soil or sediment.
IR	Adolescent	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
RAF	Adolescent	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	10 days/year for soil (site-specific information and professional judgment)
			5 days/year for sediment (site-specific information and professional judgement)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989d)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 TRESPASSER EXPOSURE:

# PATHWAYS 1B AND 1D - DERMAL CONTACT WITH CHEMICALS IN SURFACE SOIL AND SEDIMENT (ADOLESCENT SITE VISITORS)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)
CF = Conversion Factor (10⁻⁶ mg/kg)

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentrations in surface soil or sediment.
		RME	Maximum observed concentration in surface soil or sediment.
ABS	Adolescent	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d)
SA	Adolescent	Average/RME	4,100 cm ² (estimated to be 25% of the 95th percentile total body surface area for males 6-17 years old; USEPA 1992d)
AF	Adolescent	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	10 days/year for soil (site-specific information and professional judgment)
			5 days/year for sediment (site-specific information and professional judgment)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989d)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2A - INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL (ADULTS AND CHILDREN)

Equation:

Intake (mg/kg-day) =  $\frac{\text{CS x IR x RAF x CF x FI x EF x ED}}{\text{BW x AT}}$ 

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/soil/day)
RAF = Relative Absorption Factor (unitless)

 $CF = Conversion Factor (10^{-6} kg/mg)$ 

FI = Fraction Ingested from Contaminated Source (unitless)

EF = Exposure Frequency (day/years) ED = Exposure Duration (years) BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentration in soil
		RME	Maximum observed concentration in soil
IR	Adult	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
	Child	Average/RME	200 mg/day (age groups less than 6 years old; USEPA 1991a)
RAF	Adult/Child	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adult/Child	Average/RME	1.0 (professional judgment)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)
ED	Adult	Average/RME	30 years (90th percentile time spent living at one residence; USEPA 1991a)
	Child	Average/RME	6 years (entire duration of age group)
BW	Adult	Average/RME	70 kg (average; USEPA 1991a)
	Child	Average/RME	15 kg (USEPA 1991a)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2B - DERMAL CONTACT WITH CHEMICALS IN SURFACE SOIL (ADULTS AND CHILDREN)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)

 $CF = Conversion Factor (10^{-6} mg/kg)$ 

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
cs	Adult/Child	Average	Average concentration in soil
		RME	Maximum observed concentration in soil
ABS	Adult/Child	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d)
SA	Adult	Average/RME	5,700 cm ² (estimated to be 25% of total body surface area; USEPA 1992d)
	Child	Average/RME	3,200 cm ² (estimated to be 40% of the total body surface area; USEPA 1992d)
AF	Adult/Child	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adult/Child	Average/RME	1.0 (professional judgment)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)
ED	Adult	Average/RME	30 years (90th percentile time spent living at one residence; USEPA 1991a)
	Child	Average/RME	6 years (entire duration of age group)
BW	Adult	Average/RME	70 kg (USEPA 1991a)
	Child	Average/RME	15 kg (USEPA 1991a)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2C - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT (ADOLESCENTS)

Equation:

Intake  $(mg/kg-day) = \frac{CS \times IR \times RAF \times CF \times FI \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/soil/day)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10⁻⁶ kg/mg)

FI = Fraction Ingested from Contaminated Source (unitless)

EF = Exposure Frequency (day/years) ED = Exposure Duration (years) BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in sediment
		RME	Maximum observed concentration in sediment
IR	Adolescent	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
RAF	Adolescent	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year (site-specific information and professional judgment)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989d)
AT .	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2D - DERMAL CONTACT WITH CHEMICALS IN SEDIMENT (ADOLESCENTS)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)
CF = Conversion Factor (10⁻⁶ mg/kg)

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in sediment.
		RME	Maximum observed concentration in sediment.
ABS	Adolescent	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d)
SA	Adolescent	Average/RME	4,100 cm ² (estimated to be 25% of the 95th percentile total body surface area for males 6-17 years old; USEPA 1992d)
AF	Adolescent	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year (site-specific information and professional judgment)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989d)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

RME = Reasonable maximum exposure.

# SITE P11/P13 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2E - INGESTION OF CHEMICALS IN DRINKING WATER (ADULTS AND CHILDREN)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CW \times IR \times EF \times ED}{BW \times AT}$ 

where:

CW = Chemical concentration in groundwater (mg/L)

IR = Ingestion rate (L groundwater/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (days)

AI	AT - Averaging Time (uays)			
Variable	Receptor	Case	Value (Rationale/Source)	
CW	Adult/Child	Average	Average concentration in groundwater.	
		RME	Maximum observed concentration in groundwater.	
IR	Adult	Average/RME	2 L/day (90th percentile; USEPA 1989d, 1991a)	
	Child	Average/RME	1 L/day (default value; USEPA 1989d)	
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)	
ED	Adult	Average/RME	30 years (90th percentile time at one residence; USEPA 1991a)	
	Child	Average/RME	6 years (entire duration of age group; USEPA 1991a)	
BW	Adult	Average/RME	70 kg (USEPA 1991a)	
	Child	Average/RME	15 kg (USEPA 1991a)	
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year (USEPA 1989)	

Key:

EPA = United States Environmental Protection Agency.

RME = Reasonable maximum exposure.

# SITE P11/P13 RELATIVE ABSORPTION FACTORS FOR INGESTION OF CONTAMINATED SOILS

Chemical Classification	Absorption Factor	Source
Semivolatile compounds		
PAHs	1.00	USEPA 1989c
PCBs	0.30	USEPA 1989c
Pesticides		
High sorption to soil	0.30	USEPA 1989c
Low sorption to soil	1.00	USEPA 1989c
Inorganics		
Lead		
Adults	0.30	USEPA 1989c
Children	0.50	USEPA 1989c
All other metals	1.00	USEPA 1989c

Key:

PAHs = Polynuclear aromatic hydrocarbons.

PCBs = Polychlorinated biphenyls.

11:UC6101/RC1286_V2-03/27/95-D2

			Tabk	Table 6-23		
		SUMMA ASSC	SUMMARY OF EXCESS CANCER RISKS ASSOCIATED WITH SITE P11/P13	ESS CANCE	R RISKS 11/P13	
			Receptor			
Pathway	Case	Adult	Adolescent	Child ^b	Risk Contributions by Exposure Route ^a	Risk Contributions by Chemical ^a
Exposure Pathways		omplete Under	Potentially Complete Under Current Site Conditions	nditions		
Trespasser Soil Contact	RME Average	1 1	4.4 x 10 ⁻⁷ 4.5 x 10 ⁻⁸	1 1	Dermal contact - 87% Soil ingestion - 13%	PCBs - 98%
Trespasser Sediment Contact	RME Average	I 1	1.8 x 10 ⁻⁷ 4.1 x 10 ⁻⁸	1.1	Sediment ingestion - 100%	Arsenic - 95% Beryllium - 4%
Exposure Pathways		omplete Under	Potentially Complete Under Possible Future Site Conditions	Site Conditions		
Future resident soil contact	RME Average	6.6 x 10 ⁻⁵ 4.8 x 10 ⁻⁶	1.1	4.3 x 10 ⁻⁵ 3.2 x 10 ⁻⁶	Dermal contact - 90% Soil ingestion - 10%	PCBs - 98%
Future resident sediment contact	RME Average	1.1	3.6 x 10 ⁻⁶ 8.2 x 10 ⁻⁷	1 1	Sediment ingestion - 100%	Arsenic - 95% Beryllium - 4%
Future residential groundwater usage, unfiltered	RME Average	8.8 x 10 ⁻⁴ 1.9 x 10 ⁻⁴	1.1	4.1 x 10 ⁻⁴ 8.7 x 10 ⁻⁵	Water ingestion - 100%	Arsenic - 90% Beryllium - 9%
Future residential groundwater usage, filtered	RME Average	3.1 x 10 ⁴ 1.5 x 10 ⁴	11	1.4 x 10 ⁻⁴ 6.7 x 10 ⁻⁵	Water ingestion - >99% Dermal Contact - <1%	Arsenic - 57% Beryllium ^b - 41% Chlordane - 1% Heptachlor epoxide - 1%

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			Table 6-24	6-24		
SUMM	ARY OF EST	FIMATED H ASSC	ED HAZARD INDICES FOR NONC ASSOCIATED WITH SITE P11/P13	ICES FOR N	SUMMARY OF ESTIMATED HAZARD INDICES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SITE P11/P13	FECTS
			Receptor			
Pathway	Case	Adult	Adolescent	Child ^b	Risk Contributions by Exposure Route ^a	Hazard Indices by Chemical ^a
Exposure Pathways		mplete under C	Potentially Complete under Current Site Conditions	ditions		
Trespasser Soil Contact	RME Average	1 1	0.017	1 1	Dermal contact - 78% Soil ingestion - 22%	
Trespasser Sediment Contact	RME Average	1-1	0.0021	1 1	Sediment ingestion - >99% Dermal contact - <1%	
Exposure Pathways		mplete Under P	Potentially Complete Under Possible Future Site Conditions	ite Conditions		
Future resident soil contact	RME Average	0.97	1 1	3.6	Dermal contact - 58% Soil ingestion - 42%	PCB-1254 - 2.7
Future resident sediment contact	RME Average	I I	0.042	1.1	Sediment ingestion - >99% Dermal contact - <1%	
Future residential groundwater usage, unfiltered	RME Average	8.5	1.1	19 4.4	Water ingestion - 100%	Arsenic - 8.0 Manganese - 7.5 Antimony - 2.0
Future residential groundwater usage, filtered	RME Average	2.9	1 1	6.7	Water ingestion - 100%	Manganese - 3.5 Arsenic - 1.8

 $^{{}^{}a}$  RME case for the receptor showing the greatest risk.  b  Hazard indices for the child were calculated using subchronic RfDs.

### COMPARISON OF ESTIMATED RISKS FROM ARSENIC: ROUTINE EXPOSURES OF THE GENERAL POPULATION vs. POTENTIAL SITE-RELATED EXPOSURES

	. Cancer Risk	Hazard Index
Routine food and drinking water consumption (25-50 µg/day ^a )	6 x 10 ⁻⁴ to 1 x 10 ⁻³	1.2 to 2.4
Ingestion of drinking water at the MCL (50 µg/L ^b )	2.5 x 10 ⁻³	4.8
Ingestion of Site Groundwater Unfiltered (37.5 μg/L) Filtered (8.21 μg/L)	7.9 x 10 ⁻⁴ 1.7 x 10 ⁻⁴	3.6 0.75
Ingestion of Sediment (37 $\mu$ g/g)	3.5 x 10 ⁻⁶	0.04

a ATSDR 1992, WHO 1991.

b USEPA 1991b.

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### 7. ECOLOGICAL RISK ASSESSMENT

#### 7.1 INTRODUCTION

General Volume I, Section 5 describes the general ecological risk assessment approach for the P11/P13 and A12/P36/P37 sites. This ecological risk assessment for the P11/P13 site includes additional site-specific information, and presents a qualitative and quantitative assessment of the potential ecological risks from site-related contaminants.

Consistent with EPA guidance (USEPA 1992a), the ecological risk assessment is divided into six subsections. Section 7.1 describes the site and the goals of this risk assessment. Section 7.2 discusses problem formulation, and identifies the site habitats and special ecological features, contaminants of ecological concern, potential exposure pathways, ecological endpoints, and an ecological conceptual site model. Section 7.3 is an exposure assessment providing quantitative or qualitative exposure scenarios and estimates for selected ecological receptors. Section 7.4 is an ecological effects assessment summarizing toxicity reference values for selected ecological receptors. A risk characterization combining the information from the exposure assessment and ecological effects assessment to obtain estimates of ecological risk posed by the contaminants of ecological concern is provided in Section 7.5, and Section 7.6 provides conclusions and recommendations of the risk assessment. For ease of comparison, tables and figures referenced in the text are grouped at the end of Section 7.

#### 7.1.1 Site Description

The P11/P13 site, which is located in the northern section of the Annex, was originally used by the Army from 1952 to 1957 for ordnance research and development. From 1957 to 1982, Building T405 was the center of laboratory work at Site P11/P13 which included research on foamed plastics, organic chemical synthesis, herbicides, and pesticides; flame testing; and meteorological research. Other buildings on the site were used for storage, housing, and other support services including a gas station at Building T410. Beginning in 1969, the site was also used for training of units from the Massachusetts State Police, the Air National Guard, and the MFFA. The MFFA has used Site P13 on a limited basis from 1982. Several buildings were used for classroom instruction and equipment storage until 1988. Car fire training and flammable liquid fire training (using a burn pan apparatus and fire extinguishers) were conducted in the parking area at the north end of Site P13 until at least the fall of 1991. The site is no longer active. As a result of past activities at Site P11/P13, soils are contaminated with metals, pesticides, and other organic chemicals.

While unauthorized personnel and visitors are prohibited from entering the Annex, trespassing is known to occur. The residences nearest Site P11/P13 are located in the Towns of Maynard and Stow which are located northeast and northwest of the Annex. The Annex

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will eventually be released by the Army and could be developed for recreational or residential use in the future.

The ecological assessment for the P11/P13 site was initiated with an ecological field survey conducted by E & E biologists in June 1993. The detailed results of this survey are provided in Section 3 of this report. The ecological survey was intended to provide a descriptive characterization, including information on upland, wetland, and aquatic habitats on and adjacent to the site, and a general map of these habitat types, to support this ecological risk assessment. Additional information is provided in earlier sections of this report, which describe site contaminants, geology, hydrology, soils, and other site characteristics. To avoid redundancy, reference is made to these sections, and to the human health risk assessment, when appropriate.

Site P11/P13 is shown on Figure 7-1. The site is 19.2 acres in size; 12.8 acres are upland and 6.4 acres are wetland. Other pertinent aspects of the physical setting of Site P11/P13 are described in Section 3.

#### 7.2 PROBLEM FORMULATION

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA 1992a). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site are then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

The problem formulation is based on information collected during the site-specific ecological characterization and hydrogeological studies, and the chemical data provided from the SI sampling effort. This phase of the ecological assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints; and the conceptual model.

#### 7.2.1 Ecosystems of Concern

In conjunction with the SI report, field studies were conducted and the ecology of Site P11/P13 and surrounding areas (19.2 acres) was characterized. This characterization involved the identification of plant and animal communities as well as observations of any actual or potential effects of chemical and/or physical stress on these biological resources. The entire ecological characterization of Site P11/P13 is presented in Section 3 of this RI report. In general, four different plant community types were identified: two upland and two wetland communities (see Figure 7-1). The following provides a brief description of these communities, principal habitats, aquatic resources, and species of concern located in the general vicinity of Site P11/P13.

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# 7.2.1.1 Open/Disturbed Area (OD)

This cover-type is located around the abandoned buildings, roads and sidewalks (see Figure 7-1). This area is vegetated with orchard grass and kentucky bluegrass, with a few multiflora rose, black locust, and red cedar shrubs/saplings scattered around the buildings.

The dense herbaceous growth in this area provides protective cover for a variety of small mammals and songbirds. In addition, the vegetation provides seeds and berries that can be eaten by many species of birds and small mammals.

No signs of stressed vegetation or wildlife were observed in this area during the field survey.

# 7.2.1.2 Deciduous Forest (AF and RM)

Two separate habitat areas characterized as deciduous forest are located on the P11/P13 site. The first area, a quaking aspen forest (AF; see Figure 7-1), occupies the northeast portion of the site. The second, a red maple-white pine forest (RM; see Figure 7-1), occupies the south and southeast portion of the site along the fenceline. The aspen forest is dominated with quaking aspen, shagbark hickory, red maple saplings and flowering dogwood, and the maple-pine forest is dominated by red maple, white pine, red oak and poison ivy.

In general, deciduous forests (maple-aspen) provide a variety of food items to a large number of species and are considered high-quality wildlife habitats. Maple seeds, buds, and flowers provide food for songbirds and small mammals. Young maple trees are favorite nesting sites for many birds (Martin et al. 1951). Oak acorns are a valuable food source that are heavily utilized during fall and winter months by upland gamebirds (ruffed grouse and turkey), small mammals, and white-tailed deer (Martin et al. 1951). In addition, the abundance of quaking aspen, which is an important wildlife food plant (Martin et al. 1951), augments the value of this forest type for wildlife.

No signs of stressed vegetation or wildlife were noted in these areas during the field survey.

#### 7.2.1.3 Forested Wetland (FW)

A relatively large wetland surrounds most of the area except for the northwestern edge of the site, and includes only one cover type: red maple-cinnamon fern (see Figure 7-1). The dominant overstory species include red maple and slippery elm, and the understory consists of eastern white pine and red maple. The herbaceous vegetation includes cinnamon fern, royal fern, skunk cabbage and jewelweed.

This wetland area supports an abundance and diversity of animal life. The moist/saturated soil conditions are attractive to a variety of amphibians, and the inundated areas provide a water source for wildlife throughout the area. In addition, red maple seeds,

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buds, and flowers and elm seeds and buds provide an important food source for songbirds and mammals (Martin et al. 1951).

## 7.2.1.4 Emergent Wetland (EW)

This small emergent wetland is located in the northeastern portion of the open/disturbed area (see Figure 7-1). The dominant vegetation includes cutgrass, slender blue iris, sensitive fern and cinnamon fern. Small shrubs including meadow sweet, northern arrowwood, and highbush blueberry are scattered throughout this wetland.

This wetland area is of moderate-to-low value to wildlife. The size of the wetland limits the diversity and number of species it can support. The dense herbaceous layer provides both food and cover for many species of songbirds and small mammals.

No signs of stressed vegetation or wildlife were observed in these wetland areas during the field survey.

#### 7.2.1.5 Aquatic Resources

No surface water resources are located within the P11/P13 site. However, there are two unnamed intermittent streams: one on the eastern boundary of the site and the other on the southern boundary. The two streams converge southeast of P11/P13 and then flow south towards Honey Brook. These intermittent streams are not likely to support fish due to their small size and low flow rate.

## 7.2.1.6 Species of Concern

One federally listed and state-listed species, and seven additional state-listed species, are known to occur within 1.5 miles of P11/P13 site (see Table 7-1). However, no species of concern were observed on site during the field surveys and no endangered or threatened species are expected to occur because of the small size of the site and the lack of suitable habitat. However, there is a moderate likelihood for the occurrence of the state-endangered Midland Sedge (*Carex mesochorea*) because of the presence of suitable habitat (exposed sandy soil in the open disturbed area).

#### 7.2.2 Potential Stressors, Exposure Pathways, and Ecological Effects

The next step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

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#### 7.2.2.1 Potential Stressors

Based on the field surveys and data collected during the SI sampling effort, other than the human disturbance/development, there appears to be only chemical stressors present at P11/P13. Because human activities have occurred for a number of years, the vegetation and wildlife reflect these changes. Therefore, the presence of human activity in the area is not considered a physical stressor to the ecological community, but rather a defining character of the existing community.

The chemical stressors present within Site P11/P13 include the contaminants of potential ecological concern identified below. In general, these contaminants could include: metals, pesticides and other organics in surface soils, subsurface soils, surface water, sediments, and groundwater.

Selection of contaminants of potential concern (COPCs) for ecological receptors was based on the general screening criteria outlined in Volume I, Sections 4 and 5. These screening criteria include local background concentrations and ecological risk-based criteria derived or obtained from published sources. The use of background concentrations and riskbased criteria to screen the data allows identification of COPCs to which ecological receptors may be highly sensitive. Because the application of these criteria is extensively discussed in the previously cited sections, they are not discussed in the ecological risk assessment for P11/P13. Section 6 of this report provides a summary of the chemical data and presents comparisons to local background concentrations.

Potentially affected media at the P11/P13 site include surface water, sediments, surface soils, subsurface soils, and groundwater. The results of screening chemicals in these media for exceedances of ecological criteria are provided below.

#### **Surface Water**

Six surface water samples were collected from the following locations: sample E3-P11-D01 was collected from the wetland west of Building T405; samples E3-P11-D02, F3-P13-D04 and E3-P13-D05 were collected in a tributary to Honey Brook; and samples E3-P13-D01 and E3-P13-D03 were collected in the drainages from the central and eastern portion of the site. These sample locations are provided in Figure 7-1.

The surface water sampling locations are shown on Figure 7-1, and the chemical results are summarized in Section 6.

A total of 11 metals detected in the surface water of the wetlands areas or streams near the P11/P13 site were found at levels above background. The metals include aluminum, arsenic, barium, beryllium, cadmium, iron, lead, manganese, silver, vanadium, and zinc. In addition, p,p'-DDD, p,p'-DDE, p,p'-DDT, and acetone were also detected in one or two samples in the surface water. Table 7-2 summarizes the results of screening chemicals with ecological risk-based criteria. Zinc was selected as an ecological COPC. The highest concentration of zinc was found at station E3-P13-D03. The remaining chemicals were not

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considered of ecological concern because exceedances of background criteria were few, and the magnitude of exceedances was not great, or were not considered ecological COPCs for the following reasons:

- The AWQC for aluminum is considered problematic by the EPA since the criterion is frequently exceeded in pristine waters where the biota are unimpaired. The toxicity of aluminum is affected by a number of factors that are not reflected in the criterion, such as the chemical form of the aluminum, the presence of complexing ligands and organic acids, and the concentration of silicon;
- According to EPA (1986), soluble barium concentrations of less than or near 50 mg/L are not considered toxic to aquatic organisms;
- According to EPA (1986), black or brown swamp waters may contain iron concentrations of several mg/L, but this iron form is naturally occurring and has little effect on aquatic life; and
- It is unlikely that the aluminum or iron detected in unfiltered surface water are site-related contaminants, because these elements are naturally abundant in rocks, soils, and sediments.

A single exceedence of local background for both manganese and vanadium occurred in sample E3-P11-D01 (from the wetland) and likely resulted from high suspended solids in the sample. Local background concentrations of manganese and vanadium in surface water were 156  $\mu$ g/L and 4.72  $\mu$ g/L, respectively. Sample E3-P11-D01 contained 530  $\mu$ g/L manganese and 7.9  $\mu$ g/L vanadium.

#### Sediments

A total of eight sediment samples was collected for chemical analysis. The sediment samples were collected from the same locations as the surface water samples, except for an additional sample collected at station E3-P11-D02. The sampling locations are shown in Figure 7-1, and the chemical results are summarized in Section 6.

Several metals detected in the sediments of the nearby wetland areas and streams of Site P11/P13 were found at levels elevated above local background (see Section 6), most likely due to high TOC levels of these stations. The highest concentrations of most metals at the site occurred at stations E3-P11-D01 and E3-P13-D01, which had TOC concentrations of 61% and 14.3% on a dry weight (DW) basis respectively. These TOC concentrations were greater than TOC levels in the designated background sediment samples, which generally contained less than 1% TOC. Mid-basin sediment from the remote New England Lakes listed in Table J-1 of Appendix J contained 14% to 23% TOC. Therefore, given the association of metals in sediments with TOC, the New England Lakes regional background levels provide a valid comparison with levels of metals in sediments at Sudbury Annex. The results of the comparison of these metal concentrations with risk-based criteria are presented in Table 7-3.

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Arsenic was selected as an ecological COPC. The highest concentration of arsenic was found at station E3-P13-D04. Despite some exceedances, the remaining metals that exceeded criteria were not considered ecological COPCs because exceedances of background or criteria were few, and the magnitude of exceedance was not great. In addition, the highest concentrations of these metals were within, or below, the range of regional background levels reported for remote New England lakes, and for unimpacted lakes and ponds in Massachusetts (see Table 7-4).

Organic contaminants detected in the Site P11/P13 sediments include p,p'-DDD, p,p'-DDE, p,p'-DDT, benzo(b)fluoranthene, fluoranthene, pyrene, and TPHC. Samples in which p,p'-DDD, p,p'-DDE, p,p'-DDT, fluoranthene, and pyrene were normalized for organic carbon are presented in Table 7-5. Table 7-3 summarizes the results of the screening with ecological risk-based criteria. None of the organic substances were selected as ecological COPCs for the Site P11/P13 sediments. The pesticides p,p'-DDD, p,p'-DDE, and p,p'DDT exceeded NOAA/ER-L guidelines, but not OME guidelines normalized for organic carbon. The OME guidelines are considered more appropriate for these pesticides, because variation in bioavailability is accounted for. The levels of PAHs are below criteria and are not considered likely to be of ecological concern. The TPHC in the sediments at Site P11/P13 are likely the residues of fuel spills. The sediments were analyzed for semivolatile and volatile organic compounds. No BTEX compounds were detected, and only low concentrations of PAHs were detected. Therefore, these TPHC residues are expected to be composed primarily of long-chain hydrocarbons, which are not considered to be of toxicological concern at the levels detected in the sediments.

#### **Surface Soils**

Fifteen surface soil samples were collected for chemical analysis from the Site P11/P13 area. These samples were collected during the site/remedial investigation sampling effort. The sampling locations are shown on Figure 7-1, and chemical results are summarized in Section 6.

Several metals detected in the surface soils of Site P11/P13 were found in one or more samples at levels above background (see Section 6). Results of the comparison to ecological risk-based criteria are shown in Table 7-6. A number of metals exceeded the riskbased criteria in one or two samples; however, only zinc and lead were selected as ecological COPCs. Zinc exceeded the lower phytotoxicity criteria at six stations and the upper phytotoxicity criteria at one station (see Table 7-6). The highest concentration of zinc was found at station P13-SO1. Lead exceeded the lower phytotoxicity criteria at four stations. The highest concentration of lead was found at Station P13-CA7. Although other metals exceeded the criteria or background, their restriction to one or two locations indicates that they are of limited ecological significance at the site.

On the basis of the screening shown in Section 6, several organic compounds were identified in site soils. For example, p,p'-DDE and p,p'-DDT were detected at eight or more stations and exceeded background concentrations at four or more stations. However, these

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pesticides and the remaining compounds are not considered ecological COPCs for the following reasons:

- The detection frequencies were relatively low and mostly isolated to one or two samples;
- In general, maximum concentrations of organics were relatively low, usually much lower than 1  $\mu$ g/g; and
- The majority of these compounds (e.g., PAHs and DDT and related compounds) are ubiquitous in soils. PAHs are also a natural product of combustion (Eisler 1987) and could be a result of burning activities at Site P11/P13.

#### **Subsurface Soil**

Seven subsurface soil samples from five boring locations and two test pit areas were collected for chemical analyses from the P11/P13 site. The sampling locations are shown on Figure 7-1, and chemical results are summarized in Section 6.

Several metals detected in the subsurface soils of the P11/P13 site were found at elevated levels when compared to background levels (see Section 6). The results of the comparisons of metals concentrations to risk-based criteria are presented in Table 7-7. On the basis of the screening, no metals were identified as COPCs, despite some exceedances. The exceedances of background or criteria were few, and the magnitude of exceedance was not great.

Although toluene and TPHC were detected at the site, they are not considered COPCs because the maximum concentration of these compounds were relatively low and isolated to one location. Moreover, since these chemicals were not detected in surface soils, exposure to ecological receptors is likely to be minimal.

#### Groundwater

Contamination of downgradient surface water and sediment is of potential concern at Site P11/P13 due to the groundwater discharge to wetland and streams habitats. However, elevated levels of metals and low levels of organic substances, including pesticides in the downgradient wells (see Tables 7-8 and 7-9), are not considered COPCs for ecological receptors at the site, except indirectly as a potential source of contamination to sediments or surface water downgradient from the site.

To evaluate groundwater as a potential source of contaminants of ecological concern, concentrations of chemicals exceeding background were compared to EPA Ambient Water Quality Criteria (AWQC) or other criteria (see Tables 7-8 and 7-9). Although several metals in groundwater exceeded these criteria as applied to the unfiltered groundwater (see Table 7-7 only aluminum and copper exceeded the criteria after adjustment for application to the filtered

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groundwater data (see Table 7-9). Since the filtered data are more relevant to interpretation of ecological risks (USEPA 1993b), aluminum and copper are the only metals in groundwater at Site P11/P13 that appear to present potential risks to aquatic life in the vicinity of the site. Of these metals, only aluminum concentrations in surface water exceeded AWQC. Aluminum is not considered a COPC for reasons provided in the discussion of surface water contaminants (see above).

# **Summary of COPCs**

The following metals were selected as ecological COPCs in surface water, sediments, and surface soils potentially affected by the activities at Site P11/P13 (see Table 7-10):

- Zinc in the surface water;
- Arsenic in the sediments; and
- Lead and zinc in the surface soils.

No other chemicals were selected as COPCs for this ecological assessment.

# 7.2.2.2 Exposure Pathways

Several ecologically relevant migration pathways for contaminants exist at the P11/P13 site (see Figure 7-2). Chemical contaminants can adversely affect plants and animals in surrounding habitats via the food chain. Moreover, wildlife in the P11/P13 area may have incidental contact with or ingestion of contaminants while foraging, nesting, or engaging in other activities at adjacent wetland areas.

Upon their release, some of the site contaminants are persistent and may be transformed to more bioavailable forms and mobilized in the food chain. Mobilization of contaminants in the terrestrial food chain could occur through the following pathways:

- Root uptake from contaminated soil by herbaceous plants;
- Contact and absorption, incidental ingestion, and feeding on contaminated food by invertebrates;
- Drinking of contaminated surface water by wildlife; and
- Consumption of contaminted vegetation or animal prey or incidental ingestion of contaminated soil by wildlife.

Like the terrestrial food chain, contaminants could be mobilized in the aquatic food chain through the following pathways:

• Uptake from surface water or sediment by aquatic macrophytes;

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- Contact and absorption, incidental ingestion, and feeding on contaminated food by aquatic invertebrates;
- Drinking of contaminated surface water by aquatic and semi-aquatic wildlife; and
- Consumption of contaminated vegetation or animal prey or incidental ingestion of contaminated sediment by aquatic and semi-aquatic wildlife.

Based on these pathways, the following general classes of ecological receptors potentially might be exposed to contaminants at the P11/P13 site:

- Terrestrial and aquatic plants growing in and around the area;
- Terrestrial invertebrates likely to occur in an open disturbed environment, and benthic or other aquatic invertebrates in the wetlands;
- Birds that forage or nest within the area;
- Small mammals that reside and/or feed within the area; and
- Other wildlife species (e.g., carnivores) that feed within the area.

#### 7.2.2.3 Ecological Effects

As discussed earlier, several site contaminants are present in soil, sediment, and surface water and exceed ecological concern levels and, therefore, may have adverse effects on biota in the vicinity of P11/P13. These COPCs include: arsenic, lead, and zinc.

Lead is of ecological concern due to its tendency to persist in the environment. Lead generally is not highly mobile in the environment but may accumulate in tissues such as bone and liver. Excessive levels of zinc in plants can cause stunted growth, but plants and animals are relatively tolerant of high zinc levels. Excessive levels of arsenic in plants can adversely affect growth. In animals, arsenic is an acute poison. Chronic exposure to arsenic can lead to appetite loss, reduced growth, blindness, degenerative changes in the liver and kidney, and heart damage.

#### 7.2.3 Ecological Endpoints

Based on the considerations shown in Tables 7-11 and 7-12, and the potential pathways and receptors identified and described in Section 7.2.2, detrimental effects (i.e., reduced survival, growth, or reproduction of individuals, with potential impacts on populations) on vegetation, aquatic invertebrates, small mammals, birds, and carnivores were selected as the assessment endpoints for the P11/P13 site ecological risk assessment.

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Due to the numerous wildlife species found in the general vicinity of P11/P13 site, it was necessary to select a few assessment endpoint species that are thought to be representative of the local wildlife populations that would utilize and frequent the area. Selection of the assessment endpoints involved determining the basic trophic structure of the communities, and listing various species in each trophic level that are common to the site. These trophic level groups were then divided into groups of species that have a similar composition of dietary food items (e.g., percent of fish, insects, birds, in diet), and a representative endpoint species was selected. The species were selected based on their potential exposure (i.e., site usage, food habitats, home range size) and susceptibility to adverse effects of the site contaminants. In addition, if a species of social significance (i.e., game species or species of concern) is known to occur in the area, that species or a surrogate species with similar habits and diet may be selected as an endpoint.

#### 7.2.3.1 Aquatic and Semi-Aquatic Endpoint Species

Following is a brief description of the habitat requirements and diet of the aquatic and semi-aquatic endpoint species selected for P11/P13 site. In addition, the reasons for selection of these species are discussed.

- Aquatic Invertebrates. The wetland area that surrounds most of the P11/P13 site supports a community of aquatic and benthic invertebrates; and numerous other aquatic invertebrates occur in the two intermittent tributaries to Honey Brook as well as in Honey Brook. Aquatic invertebrates form the base of the aquatic food chain, and are sensitive indicators of environmental contamination. Therefore, the community of aquatic invertebrates was selected as an assessment endpoint. The measurement endpoints for aquatic invertebrates include sediment or surface water toxicity reference values for each contaminant, which are provided in Section 7.2.2.1.
- Meadow Vole (Microtus pennsylvanicus). This common small mammal occurs throughout Massachusetts, occupying home ranges from 0.08 to 0.23 acres. The meadow vole builds extensive tunnel and runway systems for escape and nesting. It is found in a variety of habitats including freshwater marshes and meadows, borders of streams and lakes, open and wooded swamps, fields, pastures, and orchards. The meadow vole consumes mainly vegetable material especially tender grass, bulbs, cambium of roots and stems, seeds, and grains. It is active day and night throughout the year.

The meadow vole has been selected to represent the small mammal community residing in the wetlands at the P11/P13 site. The meadow vole is representative of the herbivores residing in the wetlands. Due to the size and hydrology of the wetlands (i.e., no open water), other herbivores such as muskrat are unlikely to make significant use of the area.

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Measurement endpoints for the meadow vole are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

Raccoon (Procyon lotor). This common mammal occurs throughout Massachusetts, occupying home ranges of greater than 100 acres. The raccoon prefers wooded areas associated with open water or wetlands and interrupted by fields. It requires a habitat where cavity trees or protected areas for denning are available. The raccoon is an opportunistic omnivore consuming worms, insects, frogs, carrion, tender buds, shoots, grass, and human garbage. Primarily nocturnal, it remains dormant through the winter, but does not hibernate (DeGraaf and Rudis 1986).

The raccoon has been selected to represent the carnivore community at the P11/P13 site. Although the weasel, ermine, and mink are other predators occurring in the general vicinity, their habitat requirements (i.e., heavy cover, near water) are more specific than the raccoon's, and they are not as tolerant of human activity. The covote and red-tailed hawk are other potential endpoint species, but their home ranges are much larger than that of the raccoon, and their use of the P11/P13 site is not likely to be significant. Measurement endpoints for the raccoon are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

# 7.2.3.2 Terrestrial Endpoint Species

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the P11/P13 site. In addition, the reasons for selection of these species are discussed.

- Herbaceous Vegetation. Plants that occur in sandy soils in the northeastern United States are likely to occur on the P11/P13 site. These plants include herbaceous species that serve as an important food source for songbirds, small mammals, and larger herbivores. In addition, potential habitat for the state-endangered Midland Sedge occurs on site (Hunt 1992). The measurement endpoints for terrestrial vegetation are the phytotoxicity reference values of each contaminant, which are provided in Section 7.2.2.1.
- White-Footed Mouse (Peromyscus leucopus). This common small mammal occurs throughout Massachusetts, occupying home ranges

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from 0.06 to 0.54 acres. It is found in a variety of habitats, including interiors and edges of deciduous and coniferous forests, scrub areas, clearings, pastures, stream-side thickets, and buildings. The white-footed mouse consumes seeds, acorns, fruit, herbaceous foliage, insects, and, occasionally, carrion. It is active throughout the year, nesting in cavities under stumps and logs and in buildings (DeGraaf and Rudis 1986).

The white-footed mouse has been selected to represent the small mammal community at the P11/P13 site. As a receptor with an omnivorous diet that includes both plants and insects, the whitefooted mouse is representative of herbivorous and insectivorous small mammals present within the boundaries of the P11/P13 site. In addition, due to the scarcity of herbaceous plants in the vicinity, larger herbivores such as rabbits and deer are unlikely to make significant use of the area.

Measurement endpoints for the white-footed mouse are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

American Robin (Turdus migratorius). The American robin is a common year-round resident in Massachusetts. A typical density, measured during the breeding season, is 132 birds per 100 acres, each with an approximate home range of ½ acres. Breeding robins prefer open woodlands and woodland edges and clearings, fields, orchards, and shade trees in residential areas. Preferred food items include wild and cultivated fruits, earthworms, and insects (DeGraaf and Rudis 1986).

The robin has been selected to represent the songbird community at the P11/P13 site. As a receptor with an omnivorous diet that includes both plants and insects, the American robin is representative of herbivorous and insectivorous birds present within the boundaries of the P11/P13 site.

Measurement endpoints for the robin are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

Red Fox (Vulpes vulpes). This common mammal occurs throughout Massachusetts, occupying home ranges of greater than 100 acres. The red fox prefers a mixture of open and forest habitats, using the edges extensively. It requires habitat where soil conditions are

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suitable for digging dens, but may also use existing burrows. The red fox is active throughout the year and is an opportunistic omnivore, consuming insects, birds, small mammals, amphibians, eggs, berries, and fruit. Larger mammals such as the porcupine and white-tail deer may also be included in the diet (DeGraaf and Rudis 1986).

The red fox has been selected to represent the terrestrial carnivore community at the P11/P13 site. The coyote and red-tailed hawk are other potential endpoint species, but their home ranges are much larger than that of the red fox, and their use of the P11/P13 site is not likely to be significant.

Measurement endpoints for the red fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

# 7.2.4 Ecological Conceptual Site Model

In accordance with recent EPA guidance (USEPA 1992a), a conceptual model was developed to evaluate how chemical stressors from the P11/P13 site may impact ecological components of the natural environment (see Figure 7-2). This model illustrates the relationship between the ecosystem at risk, including the assessment endpoint species, and the chemical stressors. In addition, the contaminated media, exposure routes, and environmental transport are identified in the conceptual site model.

Ecological receptors evaluated in this risk assessment include representative species of terrestrial habitats (herbaceous plants, small mammals, songbirds, and carnivores) and species of aquatic habitats, including aquatic invertebrates and semi-aquatic receptors, that are likely to utilize both the wetland area and the upland grassland. Effects evaluated are based on published scientific studies and include the estimated/calculated, or predicted effects of the contaminants of concern on the survival, growth, and reproduction of these receptors.

#### 7.3 EXPOSURE ASSESSMENT

This section includes only site-specific information pertinent to the assessment of potential ecological exposures to contaminants at the P11/P13 site. General descriptions of the exposure assessment process can be found in Volume I, Section 5. General discussions of ecosystems of concern, pathways, and COPCs at the P11/P13 site are provided in Section 7.2.

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# 7.3.1 Exposure Point Concentrations

The exposure media of ecological concern at the P11/P13 site include surface water, sediments, and surface soils. As in the human health risk assessment, two cases of exposure are considered: the average exposure case and the reasonable maximum exposure (RME) case. Exposure point concentrations (EPCs) calculated for the average exposure case are the average surface water, sediment, or soil concentrations of COPCs. For the RME case, the maximum concentrations of metals selected as COPCs were used. These values are provided in Table 7-13.

# 7.3.1.1 Surface Water and Sediments

Since both the wetlands and Honey Brook ecosystems are hydrologically connected and because Honey Brook is a sluggish, slow moving stream, these ecosystems are considered as a whole in this ecological risk assessment. Exposure concentrations for sediments were estimated from data for all sediment samples collected from the wetlands surrounding the site and from the two tributaries during the SI sampling phase. Moreover, exposure concentrations for surface waters were estimated from the SI data.

#### 7.3.1.2 Soils

Exposure point concentrations for soils were estimated from surface soil data collected from SI sampling (see Section 6.3.3.1).

# 7.3.2 Exposure Scenarios and Pathways

As explained previously, four wildlife scenarios were selected for the quantitative ecological risk assessment: a small mammal, a songbird, a semi-aquatic carnivore and a terrestrial carnivore. The small mammal is represented by the white-footed mouse; the songbird species is represented by the American robin; the semi-aquatic carnivore is represented by the raccoon; and the terrestrial carnivore is represented by the red fox. The exposure parameters used to estimate exposure through incidental ingestion of soil, sediment, and surface water, and exposure through the food chain for these receptors, are provided in Table 7-14.

The exposure parameters shown in Table 7-14 were derived or obtained from EPA's wildlife exposure factors handbook (USEPA 1993c). An exposure duration of 0.66 year was used for the American robin to account for the migratory behavior of this bird (that is, onethird of the year is spent wintering away from the site).

To estimate exposure through the terrestrial and aquatic food chains, bioaccumulation factors (BAFs) for sediment and soils were derived from published sources as described in Volume I, Section 5. Using these BAFs, tissue levels in potential prey items of the endpoint species were calculated for the average exposure case (see Tables 7-15 and 7-16), and the RME case (see Tables 7-17 and 7-18).

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# 7.3.3 Exposure Estimates

Dietary exposure and exposure from ingestion of soil, sediment, or surface water for each wildlife receptor species were calculated as described in Volume I, Section 5. The estimated exposures for terrestrial herbaceous vegetation were assumed to be equal to surface soil concentrations of COPCs, as shown in Table 7-13. The estimated exposures for aquatic invertebrates were assumed to be equal to the surface water and sediment concentrations of COPCs, as shown in Table 7-13.

In cases where a particular chemical is a COPC in one or more medium but not in other media, an approach was taken to evaluate exposure only for those media where the chemical is considered a COPC.

Exposure estimates for semi-aquatic and terrestrial wildlife are shown in Table 7-19 and were calculated based on the following assumptions.

### 7.3.3.1 Semi-Aquatic Wildlife

The meadow vole was assumed to confine its feeding activities to the wetlands. Therefore, this receptor could be exposed to COPCs occurring in surface water or sediment, either directly or indirectly via the aquatic food chain. Exposure from direct contact and ingestion was calculated for COPCs in surface water and sediment. These exposure estimates were summed together with the dietary exposure to obtain the total exposure.

The raccoon was assumed to utilize both wetland and upland habitats. Therefore, this receptor could be exposed to COPCs occurring in surface water, sediment, or soil, either directly or indirectly via the aquatic or the terrestrial food chain. Exposure from direct contact and ingestion was calculated for COPCs in all three media for the raccoon, and these exposure estimates were summed together with the dietary exposure to obtain the total exposure. It was assumed that the sediment ingestion rate was the same as the soil ingestion rate.

#### 7.3.3.2 Terrestrial Wildlife

The white-footed mouse, American robin, and red fox were assumed to confine their feeding activities to the uplands. Therefore, these receptors could be exposed to COPCs occurring in soil, either directly or indirectly via the terrestrial food chain. In addition, it was assumed that all of these upland species drink from surface water in the wetlands. Exposure from direct contact and ingestion was calculated for COPCs in soil and surface water for the mouse, robin, and fox. For each receptor, these exposure estimates were summed together with the dietary exposure to obtain the total exposure.

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#### 7.4 ECOLOGICAL EFFECTS ASSESSMENT

This section includes only site-specific information pertinent to the assessment of potential ecological effects of contaminants at P11/P13 site. General descriptions of the ecological effects assessment process can be found in Volume I, Section 5.4.

#### 7.4.1 Toxicity Reference Values

A general summary of the known adverse effects of COPCs at the P11/P13 site is provided in Volume I, Section 5.4. Published toxicity values for critical effects of COPCs are also summarized in Volume I. From this summary, a mammalian toxicity benchmark value (TBV) and an avian TBV was chosen for each chemical. NOAELs were then extrapolated from the TBV (following Opresko et al. 1994) for each endpoint species. These NOAELs are the toxicity reference values (TRVs) used to evaluate risks to each endpoint species at the P11/P13 site. TRVs for wildlife are provided in Table 7-20.

Toxicity reference values for aquatic invertebrates are the chronic water quality criteria for each COPC, as shown in Table 7-2, or the sediment criteria shown in Table 7-3. Because there are several proposed values for arsenic in sediment, it was necessary to choose one value as the TRV. The NOAA/ER-L of 33  $\mu$ g/g was selected as the most appropriate benthic invertebrate TRV for the site, because this value is the most conservative standard that is greater than regional background levels. The TRVs for herbaceous vegetation are the lower phytotoxicity value for zinc and the upper phytotoxicity value for lead provided in Table 7-6. The upper level was selected as the TRV for lead, because the lower value of 100  $\mu g/g$  is less than the background level of 150  $\mu g/g$ .

#### 7.4.2 Field Studies - Summary of Findings

During the field reconnaissance, no signs of stressed vegetation or wildlife or other signs of chemical contamination were noted.

A survey of the benthic macroinvertebrate community of Honey Brook was conducted as part of the Rapid Bioassessment survey of the Annex just below the confluence with the tributary from P11/P13 (see Appendix L). The overall biological condition of the stream was not considered to be impaired in comparison to a reference station located in Taylor Brook. But arsenic in sediment at the RBA site in Honey Brook is below the maximum concentration in sediment at P11/P13 by a wide margin, as is zinc in surface water.

#### 7.5 RISK CHARACTERIZATION

In this section, the ecological risks posed by COPCs at the P11/P13 site are identified and summarized. Risk characterization involves two major steps: risk estimation and risk description (USEPA 1992a). The risks are estimated in Section 7.5.1 using hazard quotients (HQs) calculated with estimated exposure and toxicity reference values for each endpoint species. The ratios are summarized, and the principal uncertainties of the assessment are

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discussed in Section 7.5.2. The ecological significance of the findings is discussed in Section 7.5.3.

#### 7.5.1 Hazard Quotients

Table 7-21 summarizes the wildlife HQs for the average exposure case and for the RME case. The wildlife HQs for the average exposure case were all less than 1. These results indicate that the mean concentrations of these COPCs are unlikely to pose a risk to the meadow vole, raccoon, white-footed mouse, American robin, or red fox at the P11/P13 site.

An arsenic HO slightly greater than 1 was calculated for the RME case for the meadow vole. The HQs for the RME case for raccoon, red fox, white-footed mouse, and American robin were less than 1 for all of the COPCs. The results indicate that arsenic, lead, and zinc are unlikely to pose a significant risk to any of these species.

Potential risks to aquatic organisms at the site are shown in Table 7-22 for the average exposure case and for the RME case. The average and maximum surface water concentrations of zinc exceed the TRV, suggesting that zinc may pose a potential risk to sensitive species of aquatic life. The HQ for arsenic in sediment was less than 1 for the average exposure case and only slightly greater than 1 for the RME case, indicating that this COPC pose's no more than a marginal risk to aquatic life at the P11/P13 site.

Potential risks to terrestrial vegetation at the site are shown in Table 7-23 for the average exposure case and for the RME case. An HQ greater than 1 was calculated for the average concentration of zinc. In addition, the maximum detected concentrations of zinc exceeded the most conservative reference value available for this contaminant (HQ greater than 1).

# 7.5.2 Summary of Risks and Uncertainties

Potential risks of exposure to zinc were identified for sensitive species of plants growing in the P11/P13 site for the average case and for the RME case. No other risks of adverse effects from any of the COPCs in surface soils were identified for plants or wildlife for the average case. Potential risks of adverse effects on aquatic invertebrates were also identified for zinc in surface water, based on comparison of zinc concentrations to the EPA Ambient Water Quality Criterion.

Uncertainty in the risk estimates may arise during any stage in the ecological risk assessment process. Incorrect assumptions may be made regarding the potential effects of a stressor, the ecosystems of concern or the species residing within those ecosystems. Generally, care was taken to fully assess and incorporate field observations into the decision process during problem formulation to minimize these uncertainties.

The principal uncertainties in the exposure assessment have to do with quantitative estimates of exposure parameters such as BAFs. These parameters typically are chemical specific, species specific, and site specific (Rowan and Rasmussen 1992). To minimize

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uncertainty in the selection of parameters for the exposure assessment, E & E used site specific data when available. When site-specific data were not available, exposure parameters for COPCs were taken from the literature or calculated from literature data. Data on contaminants in wild animals, as opposed to domestic or laboratory animals, were used when available. Generally, the reasonable worst case was assumed to provide a conservative estimate.

Bioavailability of zinc in site surface water is an important uncertainty in the risk assessment. The EPA Ambient Water Quality Criterion for zinc is derived primarily from the laboratory bioassays in which zinc was added as an inorganic salt that readily dissociates, thus making nearly all of the zinc bioavailable. However, in natural waters such as the Annex streams and wetlands, zinc occurs in a variety of dissolved and particulate forms, of which only a fraction is bioavailable. High zinc concentrations in unfiltered samples do not necessarily imply that the water contains toxic levels of dissolved zinc.

The uncertainty associated with TRV derivation is discussed in Volume I, Section 5.4.

In general, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the site, because of the conservative nature of the assumptions used.

# 7.5.3 Ecological Significance

The P11/P13 site is a potential source of environmental contamination in soil within the open disturbed area. At the maximum concentration of zinc in soil, this contamination may present the potential for adverse toxicological effects to sensitive species of plants at the site. Zinc occurs in surface water at levels that could adversely affect aquatic life. There do not appear to be risks to wildlife at the site, nor are there significant ecological risks of arsenic contamination of sediments.

These potential effects are considered to have minimal ecological significance for the following reasons:

- Wildlife risks were not identified for the average exposure case. The average concentrations are representative of exposure for mobile species of wildlife, such as the American robin, red fox, and raccoon. Apex predators and wildlife with large home ranges are not likely to be adversely affected due to the comparatively limited extent of contamination.
- The RME case was based on the maximum concentration detected on site. The maximum concentration of zinc is located in the former burn pad area. If sensitive species of plants did reside in this area, a risk from chemical contamination could occur to individuals. However, the average case is more representative of exposure to the

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populations as a whole. Adverse effects at the population level are unlikely, except for plants species particularly intolerant of zinc.

- The terrestrial ecosystems in the general vicinity of the site do not appear to be impacted, as indicated by the diverse communities of plants and wildlife observed at the site.
- The benthic survey of Honey Brook did not suggest any impairment of the biological condition of the stream below the site.
- The surface water criterion for zinc was exceeded, but this criterion is overly conservative since the forms of zinc at the site are likely to be less bioavailable than the forms of zinc that occur in laboratory test situations.

# 7.6 CONCLUSIONS AND RECOMMENDATIONS

Metals and organic chemicals in soils, surface water, and sediment at the P11/P13 site are not considered to pose significant risks to populations of plants or wildlife. Levels of zinc in soils exceed reference values for plants but primarily for the maximum detected concentration of this chemical. These exceedances are not likely to be ecologically significant due to the limited extent of contamination and the disturbed nature of the habitat. Zinc found in the unfiltered surface water exceeds reference values for sensitive species of aquatic life. However, the zinc Ambient Water Quality Criterion for aquatic life is likely to be overly conservative for the site.

No further investigations of the P11/P13 site are recommended, given the minimal ecological risks that occur at the site. The site does not appear to pose threats of chemical contamination to ecological receptors that would warrant remedial action.

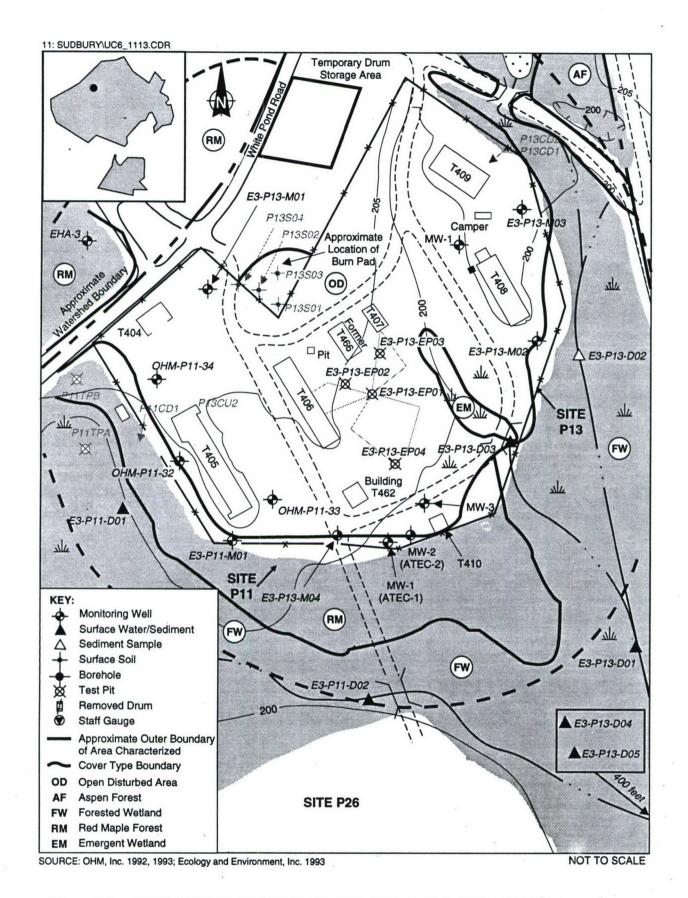


Figure 7-1 SURFACE SOIL, SUBSURFACE SOIL, SURFACE WATER/SEDIMENT,
GROUNDWATER SAMPLING LOCATIONS AND COVER TYPES AT P11/P13 SITE

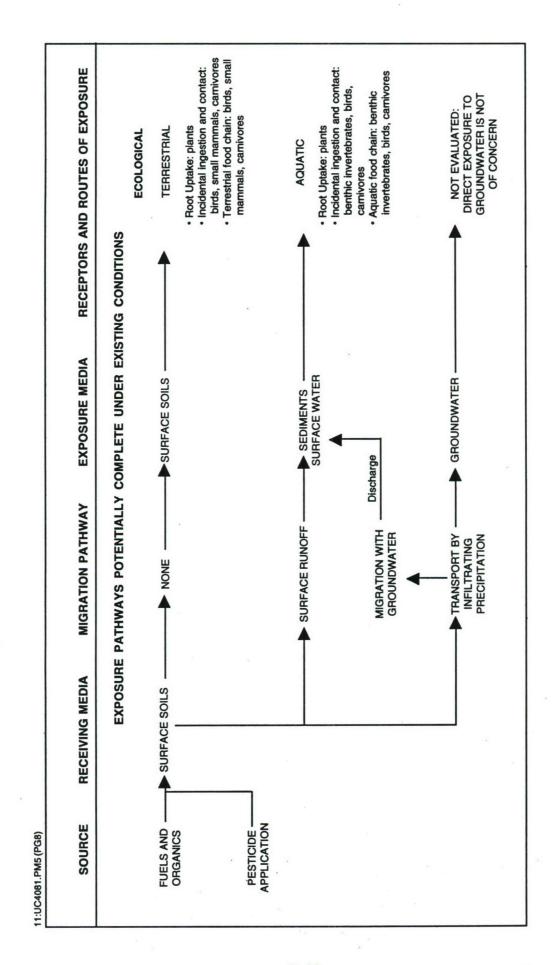


Figure 7-2 ECOLOGICAL CONCEPTUAL SITE MODEL FOR P11/P13 SITE

#### Table 7-1

# FEDERAL- AND STATE-LISTED SPECIES OF CONCERN KNOWN TO OCCUR WITHIN 1.5 MILES OF P11/P13 SITE²

Common Name	Scientific Name	Federal Status	State Status	Exposure to Site Contaminants
Birds				
Bald Eagle	Haliaeetus leucocephalus	Е	Е	Minimal: large home range
Reptiles and Amph	ibians			
Spotted Turtle	Clemmys guttata	_	SC	Moderate: suitable habitat
Blanding's Turtle	Emydoidea blandingii	_	. Т	Minimal: unsuitable habitat
Blue Spot Complex Salamander	Ambystoma laterale	-	SC	Moderate: suitable habitat
Plants				
Grass-leaved Ladies' Trees	Spiranthes vernalis	-	SC	Minimal: potential habitat occurs to the south in Taylor Drop Zone
Midland Sedge	Carex mesochorea	-	Е	Moderate: potential habitat occurs on site
Few-Seeded Sedge	Carex oligosperma	-	Т	Minimal: distribution limited to one small population in southern part of Annex
Wood Witchgrass	Panicum philadelphicum	_	sc	Minimal: potential habitat not found on site

a Species listed herein include only those species considered to be endangered, threatened, or of special concern that have been sighted within the last 10 years. This list excludes species considered as "watch list" species, and species for which suitable habitat may exist within 1.5 miles, although occurrence of the species is not confirmed. See text for further information.

#### Key:

- E = Endangered any species that is in danger of extinction throughout all or a significant portion of its range.
- T = Threatened a species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and any species declining or rare.
- SC = Special concern a species suffering a decline that could threaten the species if allowed to continue unchecked, or occurs in such small numbers or with such a restricted distribution or specialized habitat requirements that it could easily become threatened.

Source: Compiled by Ecology and Environment, Inc. 1994 from Aneptek Corporation 1991; Hunt 1992; Butler 1992.

			Tab	Table 7-2			
	SUR	RFACE WA	FACE WATER COMPARISON TO ECOLOGICAL CRITERIA SITE P11/P13 (μg/L)	ARISON TO ECOLO SITE P11/P13 (μg/L)	GICAL CRITER	ΥI	
	Rai	Range					
Chemical	Minimum	Maximum	EPA Ambient Water Quality Chronic Criteria ^a	Frequency of Exceedance of Chronic AWQC	EPA Ambient Water Quality Acute Criteria ^a	Frequency of Exceedance Acute AWQC	Exceeds Ecological Risk Criteria
Metals ^b							
Aluminum	73.0	3,500°	p.28	9/9	₂ 067	1/6	Yes
Arsenic	1.41	4.60	190 _e	9/0	360e	9/0	No
Barium	7.85	65.3 _c	NA	NA	NA	NA	NA
Beryllium	0.252 ^e	0.268	5.3 ^f	9/0	130 ^f	9/0	No .
Cadmium	1.46	1.46	0.4378	1/6	0.9958	1/6	Yes
Iron	220	5,100	1,000	3/6	NA	NA	Yes
Lead	1.24	17.3°	0.6778	9/9	17.48	0/6	Yes
Manganese	24.5	530c	NA	NA	NA	NA	NA
Silver	2.31	2.31	0.12	1/6	0.92	1/6	Yes
Vanadium	2.84	7.90	NA	NA	NA	NA	NA
Zinc	23.9	181	37.88	4/6	41.88	4/5	Yes
Pesticides							
p,p'-DDD	0.016	0.018	0.06 ^h	0/4	0.6 ^f	0/4	No
p,p'-DDE	0.019	0.055	105 ^h	0/4	1,050 ^f	0/4	No
p,p'-DDT	0.263	0.263	0.001	1/4	1.1	1/4	Yes
Volatile Organics							
Acetone	110	11°	NA	NA	NA	NA	NA

Table 7-2 (Cont.)

a U.S. Environmental Protection Agency 1986d, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless

otherwise noted.

b Only metals exceeding background are shown. ^C Average of duplicate samples.

d Criteria are pH dependent; values are valid for pH 6.5 to 9.

e Value is for Arsenic III.

f Insufficient data to develop criteria. Value presented is the Lowest Observed Effect Level.

g Hardness-dependent criteria. 29.6 mg/L hardness used. h Values are calculated from an assumed acute/chronic ratio of 10.

Key:

AWQC = Ambient Water Quality Criteria.

NA = Not available.

						Ĩ	Table /-2						
,					SEDIMENTS (Conc	S COMPARISO SIT	SEDIMENTS COMPARISON TO ECOLOGICAL CRITERIA SITE P11/P13 (Concentrations in \( \mu \)g unless otherwise noted)	CAL CRITER se noted)	Y.				
	R	Range								5.			
				Frequency of Exceedance	and	Frequency of Exceedance		Frequency		Frequency		Frequency	c.
Chemical	Min.	Max.	Guidelines Lowest Effect ^a	Guidelines Lowest Effect	Guidelines Severe Effect ^a	Guidelines Severe Effect	WDNR Guidelines ^c	Exceedance of WDNR Guidelines	ER-L Concentrations	of NOAA/ER-L Guidelines	USEPA Criteria	or Exceedance of USEPA Guidelines	Exceeds Ecological Risk Criteria
Metals													
Aluminum	2,490	8,700	NA	NA	NA	NA	NA	NA	NA	AN	AN	NA	AN
Antimony	1.01	1.01	NA	NA	NA	NA	NA	NA	2	8/0	NA	NA	No
Arsenic	0.941	37	9	2/8	33	1/8	10	3/8	33	1/8	NA	NA	Yes
Barium	10.9	59.25	NA	NA	NA	AN	200	8/0	NA	NA	NA	NA	No
Beryllium	0.062	0.632	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	1.43	1.43	9.0	1/8	10	8/0	1	1/8	5	8/0	NA	NA	Yes
Chromium	2.87	15.2	26	8/0	110	8/0	100	8/0	80	8/0	NA	NA	No
Cobalt	1.39	6.6	90	8/0	NA	NA	NA	NA	NA	NA	NA	NA	No
Copper	2.21	29.6	16	2/8	110	8/0	100	8/0	02	8/0	NA	NA	No
Iron	3,000	76,500	20,000	2/8	40,000	1/8	NA	NA	NA	NA	NA	NA	Yes
Lead	9	70.95	31	3/8	250	8/0	90	1/8	35	1/8	NA	NA	Yes
Manganese	14.4	84.3	460	8/0	1,100	8/0	NA	NA	NA	NA	NA	NA	No
Nickel	4.02	26.5	91	1/8	75	8/0	100	8/0	30	8/0	NA	NA	Yes
Selenium	0.537	2.3	NA	NA	NA	NA	1	2/8	NA	NA	NA	NA	Yes
Vanadium	2.94	26.9	NA	NA	NA	NA	NA	AN	NA	NA	NA	NA	NA
Zinc	12	370	120	2/8	820	8/0	100	2/8	NA	NA	NA	NA	Yes
Pesticides							A 55.55 A 55.5						
p.p'-DDD	0.008	0.725	0.008	1/9	6 (μg/g OC) ^b	8/0	NA	NA	0.002	8/8	NA	NA	Yes
p,p'-DDE	0.022	0.51	0.005	רור	19 (μg/g OC) ^b	8/0	NA	NA	0.002	LIL	NA	NA	Yes
TUUTU	0.013	0 00	0000	-	400 11 12 E	0,0	***		0000	!!			

Key at end of table.

11:UC6101/RC1286_V2-04/03/95-D2

recv						T	Table 7-3						
cled pape					SEDIMENTS	COMPARISO SIT	MENTS COMPARISON TO ECOLOGICAL CRITERIA SITE P11/P13 (Concentrations in 48/9 unless otherwise noted)	CAL CRITER	≰			٠	
er	Rai	Range					0						
				Frequency of Exceedance		Frequency of Exceedance		Frequency		Frequency		Frequency	
			OME	of OME Guidelines	OME	of OME Guidelines		of Exceedance	NOAA/ ER-L	Exceedance		of Exceedance	Exceeds Ecological
Chemical	Min.	Мах.	Lowest Effect ^a	Lowest	Severe Effect ^a	Severe Effect	WDNR Guidelines ^c	of WDNR Guidelines	Concen- trations ^e	NOAA/ER-L Guidelines	USEPA Criteria ^f	of USEPA Guidelines	Risk Criteria
Semivolatile Organics	nics												
Benzo(b)fluor- anthene	0.082	0.082	NA	AN	NA	NA.	NA	V.	NA	ν. V	Υ _N	٧X	NA T
Fluoranthene	0.12	0.12	0.750	8/0	1,020 (µg/g OC) ^b	8/0	1,216 (µg/g OC) ^d	8/0	9.0	L/0	620 (µg/g OC) ^b	L/0	No
Pyrene	890:0	0.068	0.490	8/0	850 (µg/g OC) ^b	8/0	NA	NA	0.35	2/0	NA	NA	No
Other Organics													,
Total Petroleum Hydrocarbons	26	263	NA .	NA	NA	NA.	NA	AN	N A	V.	V.	NA	NA A

8 From: Persaud 1993. Values shown are the lowest effect levels (a level of sediment contamination that can be tolerated by most benthic organisms) or severe-effect levels (a value of contaminant concentration that would be detrimental to the majority of benthic species), as determined by the Ontario Ministry of the Environment.

b From: Persaud 1993. Values shown are the severe-effect level normalized for organic carbon (OC).

C From: Bennett, J. and J. Cubbage, 1991. Values shown are background concentrations estimated by the Wisconsin Department of Natural Resources.

d From: Bennett, J. and J. Cubbage, 1991. Values shown are background concentrations estimated by Wisconsin Department of Natural Resources, normalized for organic carbon (OC).

From: Long E.R. and L.G. Morgan, 1991. Values shown are the Effects Range Low (ER-L), defined as the lower 10 percentile of concentrations observed or predicted to be associated with biological effects. Note that the data used to

From: USEPA 1993a. Values shown are derived from water criteria using the equilibrium partitioning approach, and normalized for organic carbon (OC). estimate ER-L are principally from marine and estuarine environments.

Only metals exceeding backgroundare shown.

Key:

Not available. NA =

National Oceanic and Atmospheric Administration. NOAA

The Ontario Ministry of the Environment. OME

Wisconsin Department of Natural Resources. WDNR

Key at end of table.

Table 7-4

COMPARISON OF SEDIMENT RESULTS TO REGIONAL BACKGROUND

SITE P11/P13 (μg/g)

Chemicala	Site P11/P13b	Ministers Pond	New England Lakes ^c	Massachusetts ^d
Aluminum	8,700	3,835	58,300	NA
Arsenic	37	4.28	13	25
Barium	59.25	39.1	282	NA
Beryllium	0.6315	NA	7.8	NA
Cadmium	1.43	0.836	3.0	5
Chromium	15.2	9.17	30	30
Cobalt	9.9	5.8	5.4	. NA
Copper	29.6	7.46	20	70
Iron	76,500	7,663	71,800	30,000
Lead	70.95	29	310	200
Manganese	84.3	46.4	4,930	350
Nickel	26.5	14.9	11	35
Selenium	2.3	NA	4.6	NA
Vanadium	26.9	12.0	142	60
Zinc	370	36.8	400	250

a Only metals exceeding site-specific background or ecological criteria are shown.

Key:

NA = Not available.

b Values shown are the maximum detected concentrations in sediments, Site P11/P13.

C Values shown are the maximum of the range of concentrations reported for remote New England lakes.

d Values shown are levels considered normal in Massachusetts lakes and ponds (from Rojko 1990).

Key at end of table.

SUMMA	Table 7-5 SUMMARY OF SEDIMENT CONTAMINANTS NORMALIZED FOR ORGANIC CARBON	Table 7-5 ONTAMINANTS N	ORMALIZED FOR C	RGANIC CARBON
Analyte	Sample Number ^a	Concentration (µg/g)	Total Organic Carbon (µg/g) ^b	Organic Carbon Normalized Severe Effect Level ^c (µg/g)
DDT	E3-P11-D02	0.038	63,800	7.00
	E3-P11-D03	0.01	12,000	0.14
	E3-P13-D01	0.13	610,000	1.2
	E3-P13-D02	0.012	12,800	0.15
	E3-P13-D03	0.230	26,200	0.31
	E3-P13-D04	0.019	79,800	96.0
DDD	E3-P11-D01	0.010	143,000	9.0
	E3-P11-D02	0.100	63,800	0.38
	E3-P11-D03	0.004	12,000	0.072
	E3-P13-D01	0.725	610,000	9.0
	E3-P13-D02	0.008	12,800	0.077
	E3-P13-D03	0.170	26,200	0.16
	E3-P13-D04	0.020	79,800	0.48
	E3-P13-D05	0.025	35,400	0.21
DDE	E3-P11-D01	0.022	143,000	1.9
	E3-P11-D02	0.079	63,800	1.2
	E3-P11-D03	0.015	12,000	0.23

		Table 7-5		
SUMMARY	N OF SEDIMENT C	ONTAMINANTS N	Y OF SEDIMENT CONTAMINANTS NORMALIZED FOR ORGANIC CARBON	RGANIC CARBON
Analyte	Sample Number ^a	Concentration (µg/g)	Total Organic Carbon (µg/g) ^b	Organic Carbon Normalized Severe Effect Level ^c (μg/g)
DDE (cont.)	E3-P13-D01	0.51	610,000	1.9
	E3-P13-D02	0.022	12,800	0.24
	E3-P13-D03	0.120	26,200	0.50
	E3-P13-D04	0.037	79,800	1.52
	E3-P13-D05	0.022	35,400	0.67
Fluoranthene	E3-P11-D03	1.8	12,000	12.2
	E3-P13-D05	0.068	35,400	36.1
Pyrene	E3-P11-D03	1.4	12,000	10.2
	E3-P13-D05	0.120	35,400	30.1

 a  Only samples with concentrations above the detection limit are shown.  b  Maximum TOC multiplier is 10% (100,000  $\mu g/g).$ 

c Organic carbon normalized severe effect level is equal to the criterion in units of  $\mu g/g$  OC * fraction OC. The criteria of the Ontario Ministry of Environment are as follows:

DDD = 6  $\mu g/g$  OC

DDT = 71  $\mu g/g$ fluoranthene = 1,020  $\mu g/g$ pyrene = 850  $\mu g/g$ 

				Table 7-6			
		SURFACE	SOILS COMPA	SURFACE SOILS COMPARISON TO ECOLOGICAL CRITERIA SITE P11/P13 (#g/g)	CAL CRITERIA		
	Rai	Range					
Chemical	Minimum	Maximum	Lower Phytotoxicity Value ^a	Frequency of Exceedance of Lower Reference Value	Upper Phytotoxicity Reference Value ^a	Frequency of Exceedance of Upper Reference Value	Exceeds Ecological Risk Criteria
Metals ^b							
Aluminum	5,800	14,000	NA	NA	NA	NA	NA
Arsenic	4.36	11	15	0/15	50	0/15	No
Barium	14.4	252	NA	NA	NA	NA	NA
Cadmium	0.358	14.2	3	2/15	80	1/15	Yes
Chromium	8.2	42.7	50	0/15	100	0/15	No
Cobalt	2.65	10.7	25	0/15	50	0/15	No
Copper	3.42	550	09	2/15	125	1/15	Yes
Iron	7,300	24,000	NA	. NA	NA	NA	No.
Lead	24	180	100	4/15	400	0/15	Yes
Manganese	81.8	460	1,500	0/15	3,000	0/15	No
Mercury	0.094	0.426	0.3	1/15	5	0/15	Yes
Nickel	2.55	30.9	100	0/15	100	0/15	NA
Vanadium	11.3	109	50	1/15	150	0/15	Yes
Zinc	21.5	910	70	6/15	400	1/15	Yes

^a From: Kabata-Pendias and Pendias 1992. Values are minimum or maximum of the range of concentrations regarded as phytotoxic by various authors. b Only metals exceeding background are shown.

Key:

NA = Not available.

_				Table 7-7			
SUBS	SUBSURFACE		COMPARISO	SOILS COMPARISON TO ECOLOGICAL CRITERIA SITE P13/P11 (μg/g)	L CRITERIA SI	TE P13/P11	
	Range	ge					
Chemical Min	Minimum	Maximum	Lower Phytotoxicity Value ^a	Frequency of Exceedance of Lower Reference Value	Upper Phytotoxicity Reference Value ^a	Frequency of Exceedance of Upper Reference Value	Exceeds Ecological Risk Criteria
Metals ^b							
Barium	12.3	28.3	NA	NA	NA	NA	NA
Cadmium	0.586	13.1	3	7/2	8	1/7	Yes
Copper	4.72 ^c	1.91	09	1/0	125	<i>L</i> /0	No
Iron	6,150 ^c	16,000	NA	NA	NA	NA	NA
Manganese	55.8	120	1,500	1/0	3,000	<i>L</i> /0	No

a From: Kabata-Pendias and Pendias 1992. Values are minimum or maximum of the range of concentrations regarded as phytotoxic by various authors.
 b Only metals exceeding background are shown.
 c Averge of duplicate samples.

Key:

NA = Not available.

ı.			Table 7-8				
GROUNDWATER COMPARI	R COMPARISC	ON TO ECOLO	OGICAL CRITE SITE P11/P13 (#g/L)	SON TO ECOLOGICAL CRITERIA DOWNGRADIENT WELLS (UNFILTERED) SITE P11/P13 (μg/L)	ADIENT WEL	LS (UNFILTER	ED)
	Rar	Range					
			EPA Ambient Water Quality Chronic	Frequency of Exceedance of	EPA Ambient Water Quality Acute	Frequency of Exceedance of	Exceeds Ecological
Chemical	Minimum	Maximum	Criteria	Chronic AWQC	Criteria*	Acute AWQC	Risk Criteria
Metals ^b							
Aluminum	122	34,000	87c	17/17	750c	14/17	Yes
Antimony	2.39	12.3	30	0/17	88	0/17	No
Arsenic	0.83	37.5	190d	0/17	850	0/17	No
Barium	7.13	198	NA	NA	NA	NA	NA
Beryllium	0.175	1.61	5.3e	0/17	130e	0/17	No
Cadmium	2.06	3.45	0.6387 ^f	3/17	1.719 ^f	3/17	Yes
Chromium	4.86	64.41	11 ^h	71/7	16 ^h	5/17	Yes
Chromium	4.86	64.41	113.7 ^f ,8	0/17	953.9 ^{f,8}	0/17	No
Cobalt	4.03	26.35 ⁱ	NA	NA	NA	NA	NA
Copper	1.54	45.35 ⁱ	6.338	8/17	8.98	8/17	Yes
Iron	385	38,000	1,000	12/17	NA	0/17	Yes
Lead	3.98	80.2	1.258	8/17	32.08	1/17	Yes
Manganese	9.38	588.5	NA	NA	NA	NA	NA
Nickel	8.17	61.55 ⁱ	84.928	0/17	763.88	0/17	No
Vanadium	4.14	69.85	NA	NA	NA	NA	NA
Zinc	29.4	416	57.038	10/17	62.98	10/17	Yes

Key at end of table.

			Table 7-8				
GROUNDWATER COMPARISON TO ECOLOGICAL CRITERIA DOWNGRADIENT WELLS (UNFILTERED) SITE P11/P13 (μg/L)	R COMPARISC	N TO ECOLC	OGICAL CRITEI SITE P11/P13 (μg/L)	ERIA DOWNGR 3	ADIENT WEL	LS (UNFILTER	ED)
	Range	ıge					
Chemical	Minimum	Maximum	EPA Ambient Water Quality Chronic Criteria ^a	Frequency of Exceedance of Chronic AWQC	EPA Ambient Water Quality Acute Criteria ^a	Frequency of Exceedance of Acute AWQC	Exceeds Ecological Risk Criteria
Semivolatile Organics							
Bis(2-ethylhexyl)phthalate	5.6	5.6	360	0/11	400	0/11	No ·
beta-BHC	0.033	0.033	NA	NA	100e	0/17	No
delta-BHC	0.033	0.058	NA	NA	100e	0/17	No
Endosulfan, A	0.028	0.028	0.056	0/17	0.22	0/17	No
Other Organics							
Total Petroleum Hydrocarbons	187	535	NA	NA	NA	NA	NA

a United States Environmental Protection Agency 1986d, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless otherwise noted.

Key:

AWQC = Ambient Water Quality Criteria. NA = Not available.

b Only metals exceeding background are shown.

^C Criteria are pH-dependent; values are valid for pH of 6.5 to 9.

d The value is for Arsenic III.

e Insufficient data to develop criteria. Value presented is the Lowest Observed Effect Level.

f The value is for Chromium III.

g Hardness-dependent criteria. 48.1 mg/L hardness used.

h The value is for Chromium VI.

i Average of duplicate samples.

			Tal	Table 7-9			
Ö	GROUNDWATER	3000	TO ECOLOGICA SITE	GICAL CRITERIA D SITE P11/P13 (#g/L)	COMPARISON TO ECOLOGICAL CRITERIA DOWNGRADIENT WELLS (FILTERED) SITE P11/P13 (#g/L)	WELLS (FILTERE	(D)
	H	Range					
Chemical	Minimum	Maximum	EPA Ambient Water Quality Chronic Criteria ^a	Frequency of Exceedance of Chronic AWQC	EPA Ambient Water Quality Acute Criteria ^a	Frequency of Exceedance of Acute AWQC	Exceeds Ecological Risk Criteria
Metals ^b							
Aluminum	121	121	87c	1/15	750 ^c	0/15	Yes
Arsenic	1.12	6.5	180.5 ^{d,h}	0/15	360 ^d	0/15	No
Chromium	5.17	6.16	9.58,h	0/15	168	0/15	No
Chromium	5.17	6.16	79.9e,f,h	0/15	705.3 ^{e,f}	0/15	No
Copper	1.52	4.21	3.9 ^{6,h}	2/15	6.27 ^f	0/15	Yes
Manganese	12.6	271	NA	NA	NA	NA	NA
Vanadium	11.1	11.1	NA	NA	NA	NA	NA
Zinc	22.9	22.9	35.5f.8	0/15	46.07 ^f	0/15	No

a U.S. Environmental Protection Agency 1986d, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless otherwise noted.

b Only metals exceeding background are shown.

^c Criteria are pH-dependent; values are valid for pH of 6.5 to 9.

d The value is for Arsenic III.

e The value is for Chromium III.

f Hardness-dependent criteria. 33.3 mg/L hardness used.

g The value is for Chromium VI.

U.S. Environmental Protection Agency 1993b. Values are for chronic criteria for the protection of aquatic life adjusted for dissolve metals.

Key:

AWQC = Ambient Water Quality Criteria. NA = Not available.

# Table 7-10 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN SITE P11/P13 Chemical Surface Water Sediment Surface Soil Metals — X — Arsenic — X — Lead — — X Zinc X — X

Key:

X = Selected as a COPC for the ecological risk assessment.

# **Table 7-11**

# AQUATIC HABITAT ASSESSMENT ENDPOINTS P11/P13 SITE

		Assessment Endpoints	
Considerations for Selection of Assessment Endpoints	Aquatic Invertebrates	Semi-aquatic Herbivore, Meadow Vole (Microtus pennsylvanicus)	Semi-aquatic Predator/Raccoon ( <i>Procyon lotor</i> )
Ecological relevance	Base of the aquatic food chain.	Herbivore: feeds on aquatic and wetland vegetation. Important food item for higher trophic levels.	Carnivore with an omnivorous diet: feeds on worms, insects, frogs, fish, small mammals, carrion and plants.
Regulatory and social significance	Water and sediment quality criteria are frequently based on toxicity testing of aquatic invertebrates.	None.	Important fur-bearing animal.
Measurability or predictability	Levels of contaminants in sediments and surface water were measured and can be related to toxicity benchmarks derived from regulatory criteria or literature.	Levels of contaminants in sediment and surface water were measured and levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Levels of contaminants in soil, sediment, and surface water were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.
Susceptibility to COPCs	Aquatic invertebrates are sensitive indicators of surface water or sediment contamination.	Vulnerable to exposure through food chain, direct contact (i.e., burrowing) or through sediment or surface water ingestion.	Vulnerable to exposure to COPCs through food chain, also through ingestion or contact with surface water, sediment, and soil.

5-D2
28/9
2-03/
7-98
C12
7.78

		Table 7-12		
	TERRESTR	TERRESTRIAL HABITAT ASSESSMENT ENDPOINTS P11/P13 SITE	ENT ENDPOINTS	
		Assessmen	Assessment Endpoints	
Considerations for Selection of Assessment Endpoints	Herbaceous Vegetation	Small Mammal/ White-footed mouse (Peromyscus leucopus)	Songbird/ American Robin (Turdus migratorius)	Carnivore/Red Fox (Vulpes vulpes)
Ecological relevance	Native grass and forb species provide food and cover for wildlife; reduce erosion in grassland habitats.	Omnivore: feeds on seeds, fruit, plants, insects, and carrion. Important food item for higher trophic levels.	Omnivore: feeds on insects, earthworms, and fruits.	Omnivore: feeds on small mammals, birds, turtles, insects, and some plants/fruits.
Regulatory and social significance	Potential habitat for species of concern (see Table 7-1).	None.	Familiar migratory bird in residential areas.	Important fur-bearing mammal.
Measurability or predictability	Levels of contaminants in soils were measured.  These levels can be related to toxicity benchmarks derived from the literature	Levels of contaminants in soils were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Levels of contaminants in soil were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Levels of contaminants in soils were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.
Susceptibility to COPCs	Vulnerable to exposure through root uptake.	Vulnerable to exposure through food chain, direct contact (i.e., burrowing), or through soil ingestion.	Vulnerable to exposure to COPCs through food chain, or through ingestion of soil.	Vulnerable to exposure to COPCs through food chain.

#### **Table 7-13**

### EXPOSURE POINT CONCENTRATIONS FOR COPCS P11/P13 SITE

	Surface	e Water	Sedi	ment	Surfac	e Soil
Chemical	Average Concentration (µg/L)	Maximum Concentration (µg/L)	Average Concentration (µg/g)	Maximum Concentration (μg/g)	Average Concentration (µg/g)	Maximum Concentration (μg/g)
Metals						
Arsenic	NC	NC	8.02	37	NC	NC
Lead	NC	NC	NC	NC	72.4	180
Zinc	72.5	181	NC	NC	132	910

Key:

NC = Not a COPC; therefore, exposure point concentrations were not calculated.

				Tabl	<b>Table 7-14</b>					
			EXPOSUR	E PARAME P11/P	RAMETERS FO P11/P13 SITE	EXPOSURE PARAMETERS FOR WILDLIFE P11/P13 SITE				
		Percent of Diet	- Terrestrial	of Diet - Terrestrial Food Chain ^a		Pe	Percent of Diet - Aquatic Food Chain ^a	quatic Food	Chain ^a	
Receptor	Plants	Invertebrates	Birds	Mammals	Soil	Macrophytes	Invertebrates	Herptiles	Fish	Sediment
Meadow Vole	1	I	1	1	1	%66	1 %	_	1	2%
Raccoon	42%	32%	1	2%	4%	1	14%	5%	2%	4%
American Robin	62%	38%	1	1	10%	1	Ī	I	1	1
White-footed Mouse	54%	46%	1	1	2%	-	1	I	ı	1
Red Fox	18%	4%	14%	64%	3%	1	1	1	1	1

	a A	OSTIBE PAR	Table 7-14	Table 7-14 EXPOSTIBE PAPAMETERS FOR WIT DITER	E	
	TVI	P	P11/P13 SITE	3		
Receptor	Home Range (acres) ^a	Site Use Factor ^b	Exposure Duration ^c	Drinking Rate (L/day) ^a	Ingestion Rate (kg/day) ^a	Body Weight (kg) ^a
Meadow Vole	0.23	1	1	0.00763	0.00473	0.037
Raccoon	129	0.099225	1	0.581	0.3402	7
American Robin	0.52	1	99.0	0.01078	0.01597	7.00
White-footed Mouse	0.54	1	1	0.00361	0.00327	0.019
Red Fox	124	0.103226	1	0.3995	0.24521	4.7

a USEPA 1993c.

^b Site Use Factor = site area (upland = 12.8 acres; wetland = 6.4 acres) divided by home range (acres).

^C Exposure Duration = fraction of year spent in region.

Plant Uptake Chemcial Factor ^a Arsenic 0.0		STIMATED TISSU AVERA Macrophytes Exposure Medium SED	ESTIMATED TISSUE LEVELS IN AQUATIC SPECIES  AVERAGE EXPOSURE CASE  SITE P11/P13  Macrophytes  Tissue Level  Exposure Medium  (mg/kg) ^a SED  0.008	QUATIC SPECIES CASE  Fish, Herptiles, a  BAF ^a Expo	SPECIES  Fish, Herptiles, and Benthic Invertebrates  Compare Medium  Compare M	e Level
Zinc	280	SW	20.3	1,633	SW	118

^a Dry-weight basis. See Volume I, Section 5 for method of calculation.

Key:

BAF = Bioaccumulation Factor. SED = Sediment. SW = Surface Water.

			_	<b>Table 7-16</b>				
		ESTIMATED TISSUE LEVELS IN TERRESTRIAL SPECIES AVERAGE EXPOSURE CASE SITE P11/P13	TISSUE LEV AVERAGE SI	ISSUE LEVELS IN TERRESTI AVERAGE EXPOSURE CASE SITE P11/P13	RESTRIAL CASE	SPECIES		*
	Terrestri	Ferrestrial Plants	Terrestrial Invertebrates	nvertebrates	B	Birds	Small	Small Mammals
Chemical	Plant Uptake Factor ^a	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a
Lead	0.045	3.26	0.0081	0.59	0.0073	0.53	0.0135	0.98
Zinc	1.5	198	2.1	722	06.0	119	2.31	305

^a Dry weight basis. See Volume I, Section 5 for method of calculation. All factors are calculated using soil as the exposure medium.

Key:

· BAF = Bioaccumulation factor.

		ates	Tissue Level (mg/kg) ^a	0:30	295
	8	Fish, Herptiles, Invertebrates	Exposure Medium	SED	SW
٠	QUATIC SPECIE	Fish	$ m BAF^a$	0.008	1,633 SW
<b>Table 7-17</b>	JE LEVELS IN AC RME CASE SITE P11/P13		Tissue Level (mg/kg) ^a	1.48	50.7
Table 7-17 ESTIMATED TISSUE LEVELS IN AQUATIC SPECIES RME CASE SITE P11/P13	STIMATED TISSU	Macrophytes	Exposure Medium	SED	SW
	<u>e</u>		Plant Uptake Factor ^a	0.040	280
			Chemcial	Arsenic	Zinc

a Dry-weight basis. See Volume I, Section 5 for method of calculation.

Key:

BAF = Bioaccumulation Factor. SED = Sediment. SW = Surface Water.

			L	<b>Table 7-18</b>		٠		٠
		ESTIMATED TISSUE LEVELS IN TERRESTRIAL SPECIES RME CASE SITE P11/P13	TISSUE LEV R SIT	EVELS IN TER RME CASE SITE P11/P13	RESTRIAL	SPECIES		
	Terrestr	Terrestrial Plants	Terrestrial Invertebrates	nvertebrates	B	Birds	Small	Small Mammals
Chemical	Plant Uptake Factor ^a	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a
Lead	0.045	8.1	0.0081	1.46	0.0073	1.31	0.0135	2.43
Zinc	1.5	1,365	2.1	1,911	06.0	819	2.31	2,102

^a Dry weight basis. See Volume I, Section 5 for method of calculation. All factors are calculated using soil as the exposure medium.

Key:

BAF = Bioaccumulation factor.

ESTIMA	TED EXPOSURES (E P11/P13 SIT		IFE
¥		Estimated (mg/k	
Chemical	Endpoint Species	Average Case	RME Case
nic	American Robin	NC	NC
	Meadow Vole	0.064	0.3
	Raccoon	0.0016	0.0074
	Red Fox	NC	NC
	White-footed Mouse	NC	NC
	American Robin	1.3	3.2
	Meadow Vole	NC	NC
	Raccoon	0.02	0.05

0.019

0.60

33

2.7

1.0

1.4

41

0.05

1.5

230

6.8

6.7

9.7

280

**Table 7-19** 

Red Fox

White-footed Mouse

White-footed Mouse

American Robin

Meadow Vole

Raccoon

Red Fox

Key:

Arsenic

Lead

Zinc

NC = Not a COPC, value not calculated.

a See Volume I, Section 5 for method of calculation.

#### **Table 7-20** TOXICITY REFERENCE VALUES (TRVs) FOR WILDLIFE P11/P13 SITE NOAEL $(mg/kg/d)^a$ Chemical **Endpoint Species** 2.12 American Robin Arsenic 0.111 Meadow Vole Raccoon 0.021 0.024 Red Fox 0.14 White-footed Mouse 4.58 American Robin Lead 15.9 Meadow Vole 2.98 Raccoon 3.44 Red Fox 19.9 White-footed Mouse 410 American Robin Zinc 317 Meadow Vole 59.5 Raccoon 68.9 Red Fox 399 White-footed Mouse

a Opresko et al. 1994 for NOAELs; raccoon NOAEL based on the formula provided in Volume I, Section 5 (body weight from USEPA 1993c).

	<b>Table 7-21</b>		
SUMMARY	Y OF HAZARD QUOT P11/P13 SIT		LDLIFE
		Hazard (	Quotient ^a
Chemical	Endpoint Species	Average Case	RME Case
Arsenic	American Robin	NC	NC
	Meadow Vole	0.6	2.7
	Raccoon	0.08	0.4
	Red Fox	NC	NC
	White-footed Mouse	NC	NC
Lead	American Robin	0.3	0.7
	Meadow Vole	NC	NC
	Raccoon	0.007	0.02
	Red Fox	0.005	0.01
	White-footed Mouse	0.03	0.07
Zinc	American Robin	0.08	0.6
	Meadow Vole	0.009	0.02

Raccoon

Red Fox

White-footed Mouse

0.02

0.02

0.1

0.1

0.7

a See Volume I, Section 5 for method of calculation. See Table 7-18 for Estimated Exposures, Table 7-19 for Toxicity Reference Values.

# Table 7-22 SUMMARY OF HAZARD QUOTIENTS FOR AQUATIC LIFE P11/P13 SITE

		Hazard (	Quotient ^a
Chemical	Endpoint Species	Average Case	RME Case
Arsenic	Aquatic invertebrates - water column	NC NC	NC
	Benthic invertebrates	0.2	1.1
Zinc	Aquatic invertebrates - water column	1.9	4.8
	Benthic invertebrates	NC	NC

a See Volume I, Section 5 for method of calculation. See Table 7-12 for Estimated Exposures, Table 7-2 and Table 7-3 and text for Toxicity Reference Values.

Key:

NC = Not a COPC, value not calculated.

# Table 7-23 SUMMARY OF HAZARD QUOTIENTS FOR TERRESTRIAL PLANTS P11/P13 SITE Hazard Quotient^a Chemical Average Case RME Case Lead 0.2 0.5 Zinc 1.9 13

a See Volume I, Section 5 for method of calculation. See Table 7-12 for Estimated Exposures; Table 7-5 and text for Toxicity Reference Values.

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#### 8. CONCLUSIONS AND RECOMMENDATIONS

Based on the human health risk and ecological risk assessments, no action under CERCLA is warranted at Site P11/P13.

The human health risk assessment for Site P11/P13 concluded that the risk under current site conditions did not exceed the 10⁻⁴ to 10⁻⁶ range for cancer nor a hazard index (HI) of 1.0. These risks are within the range considered acceptable by the EPA. Under an assumed residential scenario the reasonable maximum exposure (RME) cancer risk from soil is less than 10⁻⁴ for both adults and children. Non-cancer RME risks exceed an HI of 1.0, with an HI of 3.6 for children. This risk is mainly from dermal adsorption and ingestion of PCB 1254. The maximum level of PCB  $(3.4 \mu g/g)$  is above the EPA screening level of 1.0 μg/g for surface soils in residential areas, and was evaluated. The maximum level of lead found on site (180  $\mu$ g/g) is less than half the EPA recommended screening level for residential soil and was not evaluated.

The calculated cancer risk from drinking groundwater based on levels of metals in unfiltered samples exceeds 10⁻⁴. If filtered groundwater data are used and only the metals detected are assessed, then the cancer risk for adults (1.8 x 10⁻⁴) is still greater than the 10⁻⁴ to 10⁻⁶ range. The level of arsenic responsible for this estimated risk is well below the EPA Maximum Contaminant Level (MCL) for arsenic in drinking water, however.

Non-cancer risks from consumption of water containing metals at the levels found in unfiltered samples is greater than an HI of 1.0 in the RME case. Using data from filtered groundwater HIs approaching or exceeding 1.0 in the RME case for children include manganese (HI = 3.5) and arsenic (HI = 1.8). Total HIs from average exposure levels for filtered (non-turbid) groundwater were less than 1.0 for both adults and children.

Groundwater in the vicinity of the site is not a current or likely future source of water supply because of low yield of the aquifer and the presence of an existing public water supply line. The metals levels found in the on-site wells are naturally occurring, and are not the result of site contamination.

The ecological risks represented by the site are minimal. Zinc in surface soils exceeded reference values for plants, but only in the maximum detected concentration. Similarly zinc in unfiltered surface water exceeded reference values for sensitive species of aquatic life. The Ambient Water Quality Criterion used for comparison is likely to be overly conservative when applied to this site.

It is recommended that, before the site is released for unrestricted use, the surface soils are cleaned up to meet the 1.0 µg/g screening level criterion for PCBs for residential soil. The risk is not sufficient to warrant a formal removal action under CERCLA, but can

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be handled by a simple administrative action. It is recommended that a No Action Proposed Plan be prepared for Site P11/P13.

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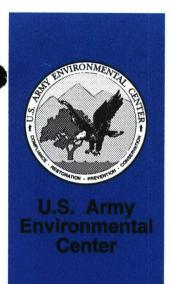
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#### **VOLUME III** SITE A12/P36/P37 REMEDIAL INVESTIGATION FORT DEVENS SUDBURY TRAINING ANNEX MAYNARD, MASSACHUSETTS

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Sudbury Annex Vol. III

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#### **PREFACE**

This is Volume III of a four-volume set that comprises the report of the remedial investigations (RIs) conducted at the Sudbury Training Annex of Fort Devens, Massachusetts. This volume contains the RI for Site A12/P36/P37. Volume II contains the RI for Site P11/P13. These reports are supplemented by the General Volume (Volume I), which provides procedural and descriptive information common to the RIs and thus eliminates the need to repeat this information in each of the reports.

Volume IV of this report set includes the appendices, which consist of field reports, special studies, and QA/QC results.

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#### LIST OF ACRONYMS

ABS Absorption Factor

ADEL Air Drop Engineering Laboratory

AMSL Above Mean Sea Level
AST Aboveground Storage Tank

AV Averaging Time
BAF Bioaccumulation Factor
BGS Below Ground Surface
BHC Benzenehexachloride

BNAs Base/Neutral/Acid Extractables

BW Body Weight

CERCLA Comprehensive Environmental Response, Compensation, and Liability

Act of 1980

COPCs Contaminants of Potential Concern
CS Contaminant Concentration in Soil
CW Contaminant Concentration in Water

DBH Diameter at Breast Height
DDD Dichlorodiphenyldichloroethane
DDE Dichlorodiphenyldichloroethylene
DDT Dichlorodiphenyltrichloroethane
EA Environmental Applications, Inc.

ED Exposure Duration

E & E Ecology and Environment, Inc.

EF Exposure Frequency
EM Electromagnetics
EP Equilibrium Partitioning

EPA U.S. Environmental Protection Agency

EPCs Exposure Point Concentrations ERA Ecological Risk Assessment

FC Fraction Contacted FI Fraction Ingested FS Feasibility Study

g Grams γ gamma

HHRA Human Health Risk Assessment

HQ Hazard Quotient

HVAC Heating Ventilation and Air Conditioning

IR Ingestion Rate

IRDMIS Installation Restoration Data Management Information System

IRP Installation Restoration Program

LOAEL Lowest Observed Adverse Effect Level

MA/CWA Massachusetts/Clean Water Act

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MA SMCL Massachusetts Secondary Maximum Contaminant Level

MCLs Maximum Contaminant Levels
MEP Master Environmental Plan

MNHESP Massachusetts Natural Heritage and Endangered Species Program

MS/MSD Matrix Spike/Matrix Spike Duplicates
NOAEL No Observed Adverse Effect Level
NWI National Wetlands Inventory

OHM Remediation Services Corporation, A Subsidiary of OHM

Corporation

OVA Organic Vapor Analyzer

PAH Polynuclear Aromatic Hydrocarbons or Polycyclic Aromatic

Hydrocarbons

PCB Polychlorinated Biphenyl
PEME Palustrine Emergent Wetland

QA Quality Assurance

QAPjP Quality Assurance Project Plan

QC Quality Control

RAF Relative Absorption Factor
RBA II Rapid Bioassessment Protocol II

RI Remedial Investigation

RME Reasonable Maximum Exposure
RPD Relative Percent Difference

SA Skin Area

SR Seismic Refraction
TAL Target Analyte List
TBV Toxicity Benchmark Value
TCL Target Compound List

TEPS Total Environmental Program Support

TOC Total Organic Carbon

TPHC Total Petroleum Hydrocarbons
TRV Toxicity Reference Values

USAEC United States Army Environmental Center

USAF United States Air Force

USATHAMA United States Army Toxic and Hazardous Materials Agency

USFWS United States Fish and Wildlife Service

UST Underground Storage Tank
VOA Volatile Organic Analysis
VOC Volatile Organic Compound
WHO World Health Organization
WQC Water Quality Criteria

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Revision No.: 2

Date:

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#### **EXECUTIVE SUMMARY**

The Remedial Investigation (RI) of the combined sites A12/P36/P37, the Raytheon Inc. buildings of Fort Devens Sudbury Training Annex (the Annex), Massachusetts was performed by Ecology and Environment, Inc., (E & E) for the United States Army Environmental Center (USAEC) under Total Environmental Program Support (TEPS) Contract No. DAAA15-90-D-0012, Delivery Order No. 0004. This volume reports the investigations performed and the conclusions and recommendations reached.

All three sites form a single contiguous area of clearing within a forested area along Moore Road, formerly Old Marlboro Road, in the southern part of the Annex. Site P36 comprises Building T104 and its immediate surroundings, Site P37 comprises Building T106 and its immediate surroundings, and Site A12 is an area of soil contaminated by a spill of transformer oil containing polychlorinated biphenyls (PCBs) adjacent to Building T106 and between the two site buildings.

The two buildings were built and used by Raytheon, Inc. in 1958 to fulfill contracts with the United States Air Force (USAF), and Raytheon continued to use the buildings until 1968, and again in 1969 and in 1971. They were later used by the Aero-Mechanical Engineering Laboratory of the USAF and the Air Drop Engineering Laboratory of Natick Laboratories. In 1988, a 10,000 gallon UST at Building T104 and a 10,000 gallon UST at Building T106 were removed. Transformer oil containing PCBs was spilled at Site A12 in 1985. The spill site was remediated twice in 1985 and 1986.

The site had previously been inspected and a monitoring well between the site and the Annex boundary was installed and sampled in 1991 and 1992.

The Site Investigation (SI) performed by E & E in 1993 involved well installation and groundwater sampling, geophysical surveys, an ecological survey, soil sampling, and surface water and sediment sampling. Supplementary work was performed in 1994 by taking wipe samples within Building T104 and sampling surface soils around the building, and the septic tank and septic tank drain field leading from the building. Using these data, a RI of the site was completed by incorporating human health and ecological risk assessments.

The conclusions of the human health risk assessment are that current site conditions do not represent an unacceptable human health risk. Because there is no approved risk factor at the Federal level, a Commonwealth of Massachusetts factor for the non-carcinogenic reasonable maximum exposure case was used. This resulted in a Hazard Index (HI) of greater than the EPA benchmark value of 1.0. The Massachusetts risk factor extrapolates from animal data using a thousand fold safety margin to ensure that no observable effects occur even in the most sensitive human subpopulation exposed, and so is likely to overstate risk.

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Using a future residential scenario with consumption of local groundwater, the use of data from filtered (non-turbid) samples of groundwater showed that the cancer risk was less than 10⁻⁴ for both adults and children, and the HI for non-carcinogenic risk was below 1.0. Arsenic in filtered groundwater was well below the EPA Maximum Contaminant Level (MCL) for drinking water.

Using the Massachusetts risk factors show that residential risk of exposure to soils is slightly greater than 10⁻⁴ in the reasonable maximum exposure (RME) scenario, but below 10⁻⁴ for average levels of exposure. The non-cancer risk from soils, again using Massachusetts risk factors, give a HI of 8.8 for adults and 31 for children, mostly due to assumed dermal adsorption and ingestion of PCBs. The maximum level of lead found in soils was below the EPA recommended screening level for residential soils.

The level of PCBs in surface soils is greater than the EPA recommended screening level of 1.0  $\mu$ g/g in residential areas. It is recommended that before the site is released for unrestricted use, surface soils be cleaned up to meet the 1.0  $\mu$ g/g screening level criterion. This can be done by administrative action and does not require a formal removal action under CERCLA.

The ecological risk assessment concluded that the contaminants identified at the site did not pose significant risk to populations of plants or wildlife.

It is recommended that a No Action Proposed Plan be prepared for Site A12/P36/P37.

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#### 1. INTRODUCTION

The United States Army Environmental Center (USAEC) tasked Ecology and Environment, Inc., (E & E) to conduct Remedial Investigations (RIs) at three collocated sites at the Fort Devens Sudbury Training Annex (the Annex) in Maynard, Massachusetts. This work was conducted under Contract No. DAAA15-90-D-0012, Delivery Order No. 0004. The scope of this RI includes three previously identified investigation sites at the Annex: Site A12 - PCB Spill Remediation Area; Site P36 - Former Raytheon Building T104; and Site P37 - Building T106 Underground Storage Tank (UST). Each of these three sites was identified in the initial draft of the Master Environmental Plan in 1992 for different potential contaminant concerns. Site A12 was investigated to assess the effectiveness of the remediation in 1985 and 1986 of a polychlorinated biphenyl (PCB) spill that occurred in July 1985. Site P36, or Building T104, was identified out of concern that past research activities at Building T104 may have resulted in some form of chemical contamination. Site P37, or the former UST at Building T106, was identified out of concern that the 1988 removal of the UST incompletely remediated underground petroleum contamination that resulted from the leaking UST.

These three sites are located immediately adjacent to each other in the southeastern portion of the Annex. Due to this proximity, a single RI addressing all concerns at the three sites was conducted. Henceforth, unless otherwise designated, "site" will refer to the entire area encompassing the three individual sites.

Previous remedial action at the site was conducted in 1985 and 1986 to address a PCB transformer spill that occurred in July 1985 just east of Building T104. Previous removal actions at the site include the removal of a 10,000 gallon UST attached to Building T104 and the removal of a 1,000 gallon UST at Building T106 in 1988. Previous environmental investigation at the site was conducted by OHM Remediation Services Corporation (OHM) in 1992 and consisted of a enhanced area reconnaissance of the site and its surroundings. These investigations are described below in this section.

Environmental investigation of the site conducted by E & E in 1993 and 1994 included: monitoring well installation and development; topographic surveying; ecological field surveying; exploratory pit excavation; building equipment survey; building wipe sampling; PCB field screening; test pit excavation and subsurface soil sampling; subsurface soil boring and sampling; surface soil sampling; septic tank sludge sampling; groundwater sampling; and surface water/sediment sampling. E & E field activities at this site are discussed in Section 2.

The results of field investigation and sampling were used to describe the physical characteristics of the site (Section 3), and to identify the nature and extent of contamination (Section 4). Based on the identification of sources and existing contamination identified in Section 4, the fate and transport of potential contaminants found at the site is discussed

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(Section 5). The profile of the nature and extent of contamination was also used to conduct a human health risk assessment (Section 6) and an ecological risk assessment (Section 7). Conclusions and recommendations for the site are made in Section 8, based on the risk assessment conclusions. References cited in the text are included in Section 9. Appendices containing pertinent investigatory data are in Volume IV.

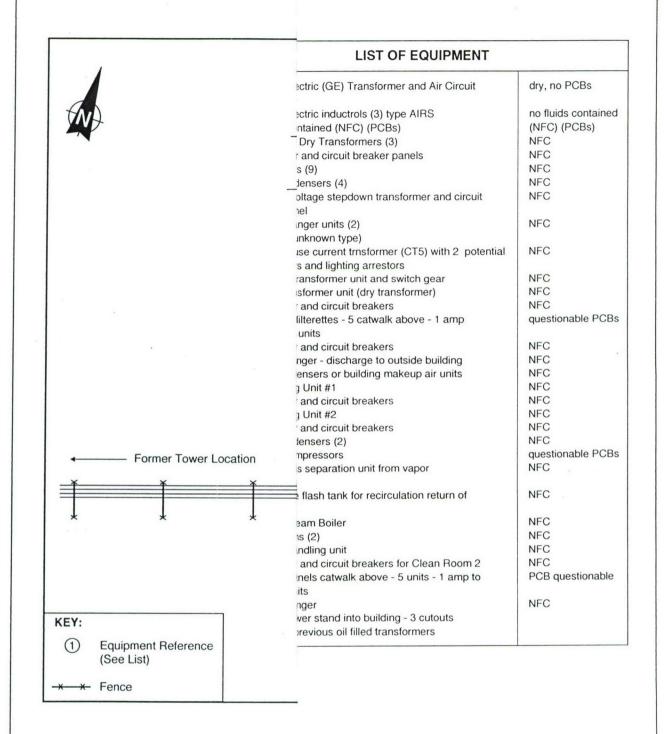
# 1.1 RI SITE LOCATION AND DESCRIPTION

The site is located in the southeastern corner of the Annex, on the south side of the Old Marlboro Road near the termination of Diagonal Road. The site location at the Annex is identified in Figure 1-2, Volume I. A site map, based on surveyed two foot contours, is enclosed as a "Plate" in the back of this volume, and displays all the sample points, site, surface features, and monitoring wells at the site, with the exception of surface water and sediment sample points. Groundwater contours and flow directions are identified on Figures 3-1 and 3-2 below. The surface water and sediment sample points are noted on the Plate at the end of Volume I.

The site consists of an area approximately 1,000 feet long by up to 250 feet wide along a northeast to southwest axis along the south side of Old Marlboro Road extending from the paved area west of Building T104 to the fence east of Building T106, and mostly within 200 feet of the road although the septic tank down field of Building T104 extends 250 feet from the road. Old Marlboro Road continues to the northeast and at the Annex boundary becomes Moore Road. Old Marlboro Road also continues to the southwest and exits the Annex at the point where the road crosses the former Boston and Maine railway line. The site contains two fabricated metal buildings, T104 and T106, which were constructed in 1958, initially for use by the Raytheon Corporation for electronic component testing and assembly under a variety of defense contracts with the United States Air Force (USAF) and United States Army. The site formerly contained a 40 foot high metal detection tower used in experiments by Raytheon that was designated Building T103. The area is partially enclosed by a 7 foot chainlink fence, mostly on the south side, but also across Old Marlboro Road opposite Building T104.

Building T103, the 40 foot metal detection tower, was formerly located approximately 100 feet southeast of Building T104, and was used for experiments by Raytheon in conjunction with research conducted in Building T104. This tower was disassembled sometime after 1971, although the concrete footings, electrical connections, and various debris from the tower are scattered around its former location. A raised trestle that carried electrical lines to the detection tower from Building T104 is still present at the site.

Building T104 is situated on the southern side of Old Marlboro Road and is 215 feet long by 87 feet wide. The building has not been in use since at least 1982, and the interior of the building shows signs of decay, including openings in the roof and the sides of the building, rusting equipment, and wiring and other infrastructure in general disarray. The layout of Building T104 and the equipment located in the building are identified in Figure 1-1 in this section. The interior of the building contains two large 'clean' rooms that were used for experimentation on electronic components. These two clean rooms are empty for the most



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part. The larger of the two rooms, hereafter referred to as "Clean Room No.1", is located in the western half of Building T104, and contains some electrical equipment including several dry-type transformers (i.e., not containing dielectric fluid), switch gear, and circuit breaker panels. This and the other clean room at Building T104 were also referred to as "the shielded area," due to the fact that the two rooms were shielded against radio frequencies to avoid interference with the electronic work conducted inside. The ceiling of the clean rooms and the rest of the building contain heating, ventilation, and air conditioning (HVAC) duct work and electrical wiring. The second clean room (Clean Room No. 2), located on the east side of Building T104, only contains one block of switch gear and circuit breakers, and HVAC duct work and electrical wiring in the ceiling. The remainder of the building including the area west of Clean Room No. 1 and the area between the two clean rooms, contains a variety of HVAC and electrical equipment. Several small transformers are located in various parts of the buildings, but none appear to be fluid-containing transformers. The building also contains three compressors for the vapor condensation system, two sets of frequency filterettes on raised platforms outside each clean room, and an oil-fired steam boiler for heating. The boiler was connected to a 10,000 gallon UST located east of Building T104, which was removed in 1988. Power to Building T104 entered on the south side of building from a transformer that was formerly located on a raised platform located approximately 30 feet south of the building. The platform is still present behind the building, but the transformer was removed in 1984.

There is an asphalt pad along the north side of Building T104, west of the entrance. This area appears to have been an outside storage area, as evidenced by the breaks in concrete footings attached to the pad and the remnants of a wooden roof still attached to Building T104 itself. Scattered metal debris is found along the north side of the building as well.

On the south side of Building T104 there is some additional metal debris and several empty metal drums. The building's septic tank and leach field, connected to the bathrooms and floor drains, are also located south of the building. The building condensation system connects from Building T104 via buried metal piping to a buried blow-down box and a dry well locate south of Building T104. The water line for Building T104 extends out the south side of the building and east toward the water well and holding tank south of Building T106.

On the northeastern side of Building T104 is the location of the PCB spill and remediation that occurred in 1985 and 1986. The cause of the spill was a leaking transformer staged about 10 to 15 feet northeast of Building T104. The transformer contained dielectric fluid containing PCBs, which leaked through a bullet hole caused by vandals using the transformer for target practice. Approximately 100 to 200 gallons of fluid drained through the hole and seeped down an asphalt pad toward a parking lot located between Buildings T104 and T106. The spill was subsequently remediated through sampling and excavation of contaminated soil in 1985 and 1986. The maximum width of the remediation area was approximately 24 feet and the maximum length was approximately 110 feet. The asphalt walkway was removed by the remediation, and the parking lot is partially covered by soil at present. The ground in the remediation area is obviously disturbed, and slopes down from Building T104 toward Building T106. There is some vegetation on the southeastern side of the spill/remediation area.

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Building T106 is located just southeast of the intersection of Old Marlboro Road and Diagonal Road, and is a fabricated metal building 187 feet long by 62 feet wide. The interior of the building is empty of equipment. On the southern side of the building, there is more metal debris, a manhole, and a former water well and holding tank that provided water for Buildings T104 and T106. On the northeastern side of the building is the former location of a 1,000 gallon heating oil UST that was removed in 1988. Beyond the fence on the eastern and the southern side of the building, the terrain is covered by forest.

#### 1.2 SITE HISTORY

The information described in this section was principally drawn from the 1994 Master Environmental Plan (MEP) (E & E 1994a) and the Phase II SI report (E & E 1994b). Where possible and necessary, the site history has been augmented by information gleaned directly from Army files, which have been made available to interested parties for review.

Building T104 was built in 1958 by Raytheon, Inc. originally to fulfill contracts for the USAF. The USAF had obtained a lease for 15 acres in early 1958 that included the land where Buildings T104 and T106 were built in mid-1958, as well as the area around the leach fields at Site A11 across Marlboro Brook. Buildings T104 and T106 were built with their own septic system and leach field and thus were never connected to the leach field of Site A11. A 10,000-gallon UST was also installed immediately adjacent to the building. The Raytheon division originally active at the Annex was the Raytheon Equipment Division Surface Radar and Navigation Operation out of Wayland, Massachusetts. Building T104, like many at the Annex, has undergone many name changes over its history. Originally known as Building S104 after construction, in internal correspondence between Raytheon and its military points of contact, the building was usually referred to as "Building No. 2." The building was also referred to as "Building S4" and as Building T104.

Building T106 has been known as S106 and S6 at other times in its history. The building was constructed in April 1958 for use by Raytheon, Inc., to use for assembling electronic equipment.

Raytheon, Inc. did not provide any information on its use of land at the Annex (in response to information requests from USAEC) stating that records are not maintained beyond contract requirements, usually 10 years (USAEC 1993). On the basis of the types of contracts held by Raytheon, Inc. at the Annex, the likely use of Building T104 was for research and development of missile guidance and radar systems and the likely use of Building T106 was for the assembly by Raytheon of electronic equipment for defense contracts both as a prime contractor and as a subcontractor. The known lease and contract information on Raytheon use of the Annex are detailed in Table 1-1.

The site was originally provided to Raytheon for research connected to the Nike-X program under which Raytheon was a major subcontractor to Bell Laboratories. Raytheon assembled and tested the receiver complex for the missile site radar (MSR), part of the Nike-X anti-missile system. Assembly of the MSR receiver was done in Building T106 and

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	Table 1-1				
RAYTHEON LEASES					
Lease	Contractor	Contract Title	Location Used		
N/A (lease begun in 1958)	Raytheon	Test "huge equipment to be developed in the area" (125 acres).	Buildings 1, 2 (also known as Buildings T104, T106)		
N/A (proposed term 1960-1965)	Raytheon	Pincushion - test prototype, possibly using a tower.	Buildings 1, 2		
DA-04-495-ORD-1951 (unknown dates)	Raytheon for General Dynamics	"Mauler"	Buildings 1,2 (Sites P36, P37)		
N/A (3 weeks in 1967)	Raytheon	Use low power Radar Range in Remote Audio Detection System Study.	Roadbed of Rocket Range/Railroad Classification Yard, Site P28		
No. 5877 (2-4 months in 1971)	Raytheon	N00017-70-C-4409: Electro-magnetic Interference Tests on NATO Sea Sparrow Guided Missile Launcher Subsystem.	Use of Building S-4 (also known as Building 2, T104)		

Source: Ecology and Environment, Inc. 1994.

testing was done in radio-frequency shielded rooms in Building T104. The original lease ran from 1958 to around 1961.

In 1960, participants of a conference between Raytheon, the Boston Air Procurement District, and the Quartermaster Research and Engineering Center (Natick) discussed a request by Raytheon to extend the current lease so that Raytheon could continue using facilities for a USAF project titled "Pincushion," involving the testing of a prototype model radar antenna. Apparently, the lease was extended and the research and testing conducted.

A 1962 facility map identified Building T104 as the "Shielded Area" and Building T106 as the "Antenna Assembly Building." A 1964 USAF memorandum noted that Raytheon was currently working for the Department of the Army on the "Mauler" program as a subcontractor to General Dynamics, and was also working under a contract for the Army Material Command. The "Mauler" program was a surface-to-air missile, and Raytheon worked on the development of the receiver system. A 1966 memorandum noted that Raytheon was using the Building T104 for testing of MSR receiver cabinets.

Raytheon apparently did not use the site between early 1968 and July 1969, when it returned to perform work under another contract. In 1971, Raytheon requested continued use of the site to conduct electromagnetic interference tests on the North Atlantic Treaty Organization (NATO) Sea Sparrow Missile Launcher System for a 2-month period in the summer of 1971. The request was addressed to the Army Missile Command at Redstone Arsenal in Alabama. This appeared to be the last use of the site by Raytheon.

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A 1971 Building Information Schedule of Natick Laboratories referred to Building T106 as "laboratory — general purpose" and noted that such use was continuing. Building T104 was designated in 1973 as "S4" for use as "Equipment Research Laboratory Electric." The two buildings retained their designations up to 1982. At some point in the 1970s, Building T106 was used by the Air Drop Engineering Laboratory (ADEL) of Natick Laboratories for parachute development. The parachute prototype shop was relocated in 1980 to the Natick Center Laboratories to conserve energy and avoid incidents of vandalism that had occurred at the site. Building T104 and the Equipment Tower No. 3 (T103), were also apparently used by ADEL during the same period.

Building T104 was also used from sometime prior to 1982 to July 1985 for the staging of transformers from Annex buildings prior to contractor repair work and/or disposal of these transformers. Sometime prior to August 1982, when Fort Devens took over the Annex from Natick Laboratories, Natick moved two Westinghouse transformers (S/N C 791819 and C 791820). One of these transformers (791820) had a plate identifying the oil type as "pyranol," an insulating oil containing PCBs. Given that the second transformer is only one serial number different from the first, it also was likely to contain pyranol. Presumably, these transformers came from buildings no longer in use at the Annex, but their exact origin could not be determined. Inspection by Fort Devens personnel in 1982 found these two transformers stored in Building T104 along with two GE transformers and two Westinghouse transformers that were part of the Building T104 design. Three of the four Building T104 transformers were still mounted into wall panels and switch panels. In December 1983, a Niagara Transformer (S/N 27351) that contained transformer oil with 98 ppm PCBs was removed from Building 411 near the North Gate and staged inside Building T104. As of June 1984, there were a total of seven transformers located in Building T104.

An inspection in July 1984 found that five of the transformers had been vandalized. All of the ceramic insulators were broken off the Niagara transformer (S/N 027351), and the transformer had to be drained, which resulted in a 30 gallon drum of transformer oil containing 98 ppm PCBs. The four Building T104 transformers had also been vandalized by scavengers seeking to strip the units of their copper. The inspection discovered that these four units turned out to be dry units containing no fluids, and thus did not require disposal. These four units are still located inside Building T104, with the GE transformers located in Clean Room No. 1 and the two Westinghouse transformers located in the electrical area in the center of the building.

In March 1985, the two GE transformers (S/N C 791819 and 791820) originally staged by Natick in Building T104, and the empty carcass of the Niagara transformer from Building 411, were moved outside Building T104 in the area just east of the building. A GE transformer (S/N D 276294) was removed from a pole riser "behind building 103" (which most likely refers to the platform actually behind Building T104), and staged next to the others just east of Building T104. These transformers were relocated outside to give "easy contractor accessibility" for Fort Devens contractors to remove and dispose of these transformers. The drum containing 30 gallons of 98 ppm PCB oil was moved to a point near the guard shack at the entrance gate.

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An inspection in April 1985 found that the GE transformer removed from the platform behind Building T104 (S/N D 276294) had been tipped over and the insulators had been broken. A small amount of oil had been discharged. The oil was pumped out and combined with the contents of the previous accumulation drum. Also, a 55-gallon drum was used to containerize spill debris from the cleanup of the ground contamination by the discharge.

On 11 July 1985, Fort Devens personnel and their contractor discovered that the GE transformer (S/N C 791820) had been punctured one third of the way up by a bullet hole. Oil had discharged and flowed down grade approximately 90 to 100 feet. The subsequent remedial efforts in 1985 and 1986 related to this PCB spill are described in Section 1.3.1.

In 1988, the 10,000 gallon heating oil UST at Building T104 and the 1,000 gallon heating oil UST at Building T106 were removed by Environmental Applications, Inc. (EA). These removals are discussed in greater detail in Sections 1.3.2 and 1.3.3 below.

# 1.3 PRIOR REMEDIAL AND REMOVAL ACTIONS

## 1.3.1 PCB Spill Remediation, 1985 to 1986

On 11 July 1985, Fort Devens Directorate of Engineering and Housing (DEH) personnel discovered that a General Electric transformer (S/N C 791820), staged near Building T104 had leaked oil containing PCBs due to a bullet hole puncture. At the time of the spill discovery, four transformers were located in the staging area. Two of the transformers had been previously drained by Fort Devens personnel, and the remaining two, including the punctured transformer, still contained fluid.

An estimated 100 to 200 gallons of PCB oil were released onto the ground. The release ran downgrade and under an asphalt-paved, 4-foot-wide walkway. The walkway led from a parking lot to a building entrance. Fluid was observed to have seeped between cracks and penetrated site soil.

From 12 July through 25 July 1985, Inland Pollution Control, Inc. took samples, drained the remaining 300 gallons of fluid from the leaking transformer, and excavated 150,490 pounds of visibly contaminated soil in the release area. Initial sampling had indicated soil contaminated with PCBs up to 12,700 ppm. Sampling by Inland Pollution on 1 August 1985, after the initial excavation, indicated PCB levels in the spill area had dropped below 3 ppm. In August 1985, the United States Army Environmental Hygiene Agency (AEHA) sampled the soil around the contaminated area and detected levels of PCBs up to 3,492 ppm from the area of excavation, and up to 508 ppm from the surrounding terrain. Additional soil removals were performed from September through November 1985, which increased the total amount of soil removed to 161 tons. Groundwater was not encountered in any of the excavation work at the site. Sampling on 19 November 1985 by AEHA indicated residual PCB levels in soil below 4  $\mu$ g/g with one area with PCB level of 10.7  $\mu$ g/g.

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A review of documents pertaining to the removal of material from the PCB spill and remediation area in 1985 indicated the following were removed: (1) in July 1985 - 300 gallons of PCB oil under Manifest Number MA B117436; 150,490 total pounds of PCBcontaminated soil under manifest number NYA 2578122, NYA2578158, NYA 2578131, and NYA 2578143; four drained transformers under manifest number MA B25781851; and two drums (one oil, one debris) under manifest number MA B117661; (2) in October and November 1985 - a total of 171,570 pounds of PCB-contaminated soil removed and transported under manifest numbers NYA 2025531, NYA 2025126, NYA 205099, NYA 2025117, and NYA 1494423 to the SCA Chemical Services facility in Model City, New York, EPA ID number NYD049836679. The transporter for the October and November removals was Inland Pollution Control, Inc., EPA ID number MAD095869459. Although the manifests for the July 1985 removals are not in E & E site files, given that Inland Pollution Control, Inc. was the remedial contractor hired by the Army in July 1985, they were probably also the transporter for the July 1985 removals. The likely destination for the contaminated soil removed in October and November 1985 was also the SCA Chemical Services facility in Model City, New York. The exact destination for the removed PCB oil and the two drums could not be identified.

In May 1986, Fort Devens, in consultation with Massachusetts Department of Environmental Protection (MDEP), collected soil samples in locations outside the original release area but within the area used by the remedial contractor to load and park equipment during the initial response. Sampling results indicated PCB levels up to 148 ppm in soils at the site. Additional soil, believed to be contaminated as a result of spillage of contaminated soil during the initial response, was excavated and removed on 19 June 1986. Further sampling on 8 July 1986 indicated residual PCB levels up to 80.0 ppm. An excavation was conducted on 18 July 1986, and extended 100 feet from the initial spill location near Building T104, with a maximum width of 15 feet at the upgradient end and a total of 11.5 cubic yards of soil was removed. Soil samples were collected up to 12 feet BGS after the excavation and analytical results found PCB levels only up to 2.5 ppm. Remediation activities were summarized in a document dated 5 August 1986 and sent to the Massachusetts Department of Environmental Quality Engineering (MDEQE). A response dated 1 March 1989 to the Environmental Management Office at Fort Devens, noted that based on the information included in the Army's 5 August 1986 letter, MDEQE did not anticipate requiring any further investigation or remedial action at the site in accordance with M.G.L Chapter 21E.

# 1.3.2 Removal of 10,000 Gallon UST at Building T104 in 1988 by Environmental Applications, Inc.

In December 1988, Environmental Applications, Inc. (EA), removed the 10,000 gallon UST located near the southeastern corner of Building T104. This UST had contained No. 2 Fuel Oil. No visibly contaminated soils or odors were noted. HNu readings of soil samples from the excavation did not indicate readings above background. No holes were observed in the tank and according to the EA removal document, the pit was backfilled with material previously classified as acceptable fill using the soil classification system outlined in its contract with the Army. No other details on backfill material were located (EA 1989).

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# 1.3.3 Removal of 1,000 Gallon UST at Building T106 in 1988 by Environmental Applications, Inc.

In December 1988, a 1,000 gallon UST used to store No. 2 Fuel Oil was removed from the northeastern corner of Building T106 by EA. Prior to the excavation, 75 gallons of waste oil were removed from the tank. The UST was reported to be in poor condition, with extensive corrosion and a 1-inch hole located in the side of the tank directly below the fill line. The soil surrounding the tank prior to removal was stained and emanated strong petroleum odors. Sixteen cubic yards of soil were removed from the tank pull area (EA 1989).

Excavation of contaminated soil ceased at the foundation of the Building T106 to avoid endangering its structural stability. Soil samples were taken from the bottom of the excavation and from the soil stockpile. Laboratory analytical results indicated concentrations of 6,521 ppm of TPHC in the excavation sample and 6,517 ppm of TPHC in the stockpile sample. The pit was backfilled with acceptable soil in December 1988. The stockpiled soil was transported to the Consolidated Wastes Services, Inc., landfill in Norridgewock, Maine, in March 1989 for disposal (EA 1989).

# 1.4 PREVIOUS INVESTIGATION BY OHM IN 1992

OHM performed an enhanced area reconnaissance of Buildings T104 and T106 and the surrounding area in 1992. Two entrances to the building were noted, and metal debris, trash, insulation, and machinery were observed within the building. Large conduits extend from the west end of the building to the former location of the observation tower, presumably for relaying electric power and/or communications between Building T104 and the observation tower. A number of large vents were noted on the south and west ends of the building. Scrap metal and trash were found throughout the site that are part of the heating, ventilation, and air-conditioning (HVAC) cooling system for Building T104. A large cable, believed to be an anchor for the tower that used to be at the site, was found south of the building, protruding from the ground. At Building T106, the enhanced area reconnaissance located scrap metal and an open manhole on the south side of the building. The manhole was found to lead to an underground vault housing the water supply well and holding tank formerly used for Building T104 and Building T106. No other investigations had been performed prior to the OHM effort (OHM 1994).

A boundary well, OHM-BW-1, was installed southeast of Site P37 in October 1991, and sampled in October 1991, and in June and October, 1992. Analyses of the sampling of this well did not indicate any pesticides, PCBs, or explosives. Bis(2-ethylhexyl)phthalate was detected in the June 1992 round at 17  $\mu$ g/L, but not in the other two rounds, and is likely a laboratory or field sampling contaminant. The only volatile organic compound was methylene chloride at 8.92  $\mu$ g/L in the October 1991 round, but not in the other two rounds. Methylene chloride is a common laboratory solvent, and this detection probably does not indicate site contamination. Since OHM used filtered sampling for all of its groundwater sampling at the Annex, the analysis results for metals were compared to the filtered sampling results from the local background well at the site (E3-P36-M01). Lead was not found in the local background

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well at a detection limit of 5.0  $\mu$ g/L, but was found in two of three rounds of sampling of OHM-BW-1 up to 3.04  $\mu$ g/L. This level however is well below the Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL) of 15  $\mu$ g/L. Magnesium (1,000  $\mu$ g/L in one of three rounds), potassium (up to 2,300  $\mu$ g/L), and zinc (up to 32.7  $\mu$ g/L) were also found in OHM-BW-1 above local background levels, but are likely to indicate natural levels of these metals. Overall results of sampling did not identify groundwater contamination at this well (OHM 1994).

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## 2. E & E FIELD ACTIVITIES AT SITE A12/P36/P37

Field activities at Site A12/P36/P37 included geophysical surveys; installation and development of monitoring wells; topographic surveys; water level measurements; aquifer testing; sampling of surface soil, subsurface soil, groundwater, surface water and sediment, building surfaces (wipe samples), and the septic system; and an ecological characterization of the site.

## 2.1 ANALYTICAL PARAMETERS AND SAMPLING EFFORTS

Most of the samples, including all of the groundwater, septic tank, test pit, surface water, and sediment samples, the boring samples collected around Buildings T104 and T106, the soil samples collected around Building T106, and the soil samples collected in 1993 around Building T104 during the field investigation, were analyzed for Target Compound List (TCL) organics, Target Analyte List (TAL) metals, and Total Petroleum Hydrocarbons (TPHC). Table 2-1 summarizes the samples by type, and includes sample dates, analysis performed, and sampling rationale for the sample collected at the site. Sample locations are identified on the Plate at the end of this report, with the exception of the Building T104 wipe samples, which are identified in Figure 4-1 and surface water and sediment sample points, which are identified on the Plate at the end of Volume I

More limited analysis was conducted for the wipe samples, the borings and surface soils collected for investigation of the PCB spill/remediation area, and the surface soils collected in April 1994 around Building T104, due to the focus of investigations regarding PCBs and TPHC in these portions of the site. Field screening for PCBs only was conducted on the 8 boring samples and 20 surface soil samples collected in August 1993 to investigate the PCB spill/remediation area east of Building T104. Of these, the boring samples and two of the surface soil samples were sent to the laboratory for TCL pesticides and PCB analysis only. The wipe samples collected in April 1994 in Building T104 were analyzed for PCBs only. The surface soils collected in April 1994 around Building T104 were analyzed for PCBs and TPHC only.

Subsurface soil samples were collected from the six wells and one boring for Total Organic Carbon (TOC) analysis to characterize the nature of subsurface soils and their potential for interaction with organic contamination in the groundwater. Geotechnical subsurface soil samples were also collected from the six wells for grain size and Atterberg limits analysis to characterize the nature of subsurface soils and their effect on the rate of movement of groundwater.

The 18 surface soil samples collected around Buildings T104 and T106 in 1993 were also analyzed for TOC to characterize the nature of surface soils at the site and their impact on sorption of potential contaminants. Two of the sediment samples were also analyzed for TOC. Geotechnical samples were collected at the three sediment sampling points and

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		Table	2-1		
	PHASE II SAMPLING EFFORT				
Sample Type	Number of Samples (Site IDs)	Sample Date(s)	Analysis ¹	Sampling Rationale	
Ground- water	12 (6 wells, 2 rounds) (E3-P36- M01/M02/M03; E3-P37- M01/M02/M03)	09/01/93, 09/02/93 12/01/93	TCL Organics, TAL Metals, TPHC	Samples were collected to characterize groundwater quality and assess the potential for contaminant migration in the groundwater pathway.	
Septic Tank	1 (E4-P36-P02)	04/27/94	TCL Organics, TAL Metals, TPHC	One sludge sample was collected from the septic tank connected to Building T104 to investigate potential contamination migration via the Building T104 septic system.	
Wipe	10 (E4-P36-I01 through I10)	04/26/94	PCBs	Wipe samples were collected from floor of Building T104 to investigate PCB contamination from existing or former equipment.	
Subsurface Soil	8 from 4 borings (E3-A12- B01/B02/B03/ B04)	08/10/93 08/11/93	PCBs (Field Screening), TCL Pests/PCBs	Samples were collected to investigate residual PCB levels in subsurface soils in vicinity of the PCB spill/remediation area.	
	3 from 1 test pit (E4-P36-P01)	04/27/94	TCL Organics, TAL Metals, TPHC	Samples were collected from a test pit across the Building T104 leach field to investigate potential contamination migration via the Building T104 septic system.	
	12 from 6 borings (E3-P36- B01/B02/B03; E3-P37- B01/B02/B03)	08/05/93, 08/06/93 08/09/93, 08/13/93 08/16/93, 12/01/93	TCL Organics, TAL Metals, TPHC	Samples were collected to assess subsurface contamination around Buildings T104 and T106.	
	6 from 6 wells (Listed Above)	08/05/93, 08/06/93 08/07/93, 08/13/93	Grain size, Atterberg limits	Geotechnical samples were collected to characterize nature of subsurface soils and the groundwater pathway.	

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		Tabl	e 2-1		
	PHASE II SAMPLING EFFORT				
Sample Type	Number of Samples (Site IDs)	Sample Date(s)	Analysis ¹	Sampling Rationale	
	6 from 6 wells, 1 from boring E3-P36-B03	08/05/93, 08/06/93 08/07/93, 08/09/93 08/13/93	тос	Samples were collected and sent for TOC analysis to characterize nature of subsuface soils and the groundwater pathway.	
	20 (E3-A12-S01 through S20)	08/24/93, 09/02/93	PCBs (Field Screening); 2 (E3- A12-S02 and S03) of 20 sent to lab for TCL Pests/PCBs	Samples were collected to investigate residual PCB levels in soils in vicinity of PCB spill/remediation area.	
,	12 (E3-P36-S01 through S12)	08/24/93 08/25/93 09/03/93 12/02/93	TCL Organics, TAL Metals, TPHC	Samples were collected to investigate surface soil contamination from areas surrounding Building T104.	
Surface Soils	6 (E3-P37- S01/S02/S03/ S04/S05/S06)	08/25/93	TCL Organics, TAL Metals, TPHC	Samples were collected to investigate surface soil contaminations from areas around Building T106.	
	6 (E4-P36- S13/S14/S15/ S16/S17/S18)	04/26/94	PCBs, TPHC	Samples were collected to investigate extent of PCB, and TPHC contamination around Building T104.	
	18 (E3-P36-S01 through S12; E3-P37-S01 through S06)	08/24/93, 08/25/93 09/03/93, 12/02/93	TOC	Samples were collected and sent for TOC analysis to characterize nature of surface soils at the site and their potential for sorption.	
Surface Water	3 (E3-P37- D01/D02/D03)	09/16/93 09/23/93	TCL Organics, TAL Metals, TPHC	Surface water samples were collected to characterize water quality in Marlboro Brook and investigated potential for off-site contaminant migration through surface water pathway.	

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Table 2-1				
PHASE II SAMPLING EFFORT				
Sample Type	Number of Samples (Site IDs)	Sample Date(s)	Analysis ¹	Sampling Rationale
Sediment	3 (E3-P37- D01/D02/D03)	09/16/93 09/23/93	TCL Organics, TAL Metals, TPHC (sediment at E3-P37-D03 also analyzed for explosives, phosphates, herbicides, and organophosphorus pesticides)	Sediment samples were collected to investigated potential off-site sediment contamination in Marlboro Brook.
	(same as above)	09/16/93	тос	Samples were collected for TOC analysis
	(same as above)	09/16/93 09/23/93	Grain size, Atterberg Limits	Geotechnical samples were collected to characterize the nature of sediments in Marlboro Brook.

¹ Laboratory analysis except as specified

Source: Ecology and Environment, Inc. 1994.

analyzed for grain size and Atterberg limits to characterize the nature of sediments in Marlboro Brook.

To further characterize water quality of Marlboro Brook where it leaves Annex property, the sediment taken at sample location E3-P37-D03 was resampled in late September 1993 and analyzed for explosives, phosphates, herbicides, and organophosphorus pesticides.

## 2.2 GEOPHYSICAL SURVEYS

Geophysical investigations were conducted around and between the two buildings at Site P36/P37. The investigations consisted of a seismic refraction (SR) and Electromagnetic Conductivity (EM) reconnaissance surveys. E & E conducted the SR survey between 20 and 26 May 1993 and the EM survey between 2 and 13 August 1993. The SR survey is used for subsurface exploration and to help create contour maps. The EM survey consists of using the EM31 meter, which continuously measures the apparent terrain conductivity of materials beneath and immediately surrounding the area.

Results from the SR survey indicate that the bedrock surface is sub-parallel with the ground surface. That is, the bedrock highs are found beneath topographic highs, and dip towards the valleys. The apparent groundwater contours also exhibit this sub-parallel attitude,

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although in the northwestern portion of the survey, the water table appears to remain fairly flat following the topography.

The EM reconnaissance survey revealed large amounts of metal on the ground near the buildings. The debris, and the two metal buildings caused a great deal of interference that masked anomalous readings from subsurface objects. Using the EM31 meter, an apparent buried pipe was located between the two buildings. This pipe appeared to be laid behind Building T104, where it extended above ground towards a concrete pad containing a vertical pipe. This pad was located approximately 40 feet south of the center of Building T106. The pipe identified in the geophysical survey is evidently the water line from Building T104 to the water well south of Building T106 (see Section 1.2).

The complete geophysical report is presented in Appendix E and the conclusions of these studies were used to develop the understanding of groundwater contours and flow presented in Section 3.

#### 2.3 MONITORING WELL INSTALLATION AND DEVELOPMENT

To characterize groundwater quality and the potential for contaminant migration, E & E installed, developed, and sampled six shallow overburden monitoring wells in the vicinity of Buildings T104 and T106. Placement of all six wells was based on the results of the seismic survey performed during the summer of 1993. All six wells were sampled during both groundwater sampling events in September and December 1993, with both filtered and unfiltered samples collected during each round.

Well E3-P36-M01 is northwest of Building T104 near the northern edge of the paved area that borders Old Marlboro Road. The monitoring well was screened across the water table at an interval 8 to 18 feet below ground surface (BGS). The well location monitors the top of the local watershed formed by the low hill of till on which Building T104 stands. It is effectively background with respect to the site. This well is located upgradient of Building T103, Building T104, the PCB spill/remediation area and Building T106. Given its location upgradient of any potential contaminant sources, this well was used to characterize local groundwater background conditions.

Well E3-P36-M02 is located along Old Marlboro Road near the northeastern corner of Building T104. The well was screened across the water table at an interval 8 to 18 feet BGS. The proximity of the well to Building T104 and the PCB spill/remediation area allows for close monitoring of any contaminant plume emanating either from the building or residually contaminated soil. The well characterizes groundwater quality in the area and the potential for off-site contaminant migration. In addition, since the well lies upgradient of Building T106, any contamination found in the groundwater can only be attributed to sources at Building T104 or in the PCB spill/remediation area.

Well E3-P36-M03 is located at the intersection of Diagonal Road and Old Marlboro Road and monitors the groundwater pathway downgradient of both Building T104 and the PCB spill/remediation area. The monitoring well was screened across the water table at an

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interval 9 to 19 feet BGS. Because it is significantly distant from any possible contaminant sources, the well monitors a relatively large portion of the groundwater pathway migrating from the western portion of the site. Since it is the downgradient well from the western portion of the site the well monitors groundwater quality prior to discharging to Marlboro Brook.

Well E3-P37-M01 is located southwest of Building T106, in the center of the clearing between Buildings T104 and T106. The monitoring well was screened across the water table at an interval of 9.5 to 19.5 feet BGS. The well is located so that contamination in the groundwater pathway can be monitored from potential sources at Building T104 or the PCB spill/remediation area.

Well E3-P37-M02 is located along Old Marlboro Road near the northwestern corner of Building T106. The well was screened across the water table at an interval 9 to 19 feet BGS. The proximity of the well to Building T106 allows close monitoring of any contaminant plume that may have resulted from the leaking UST or other activity at Building T106. Because of the well's proximity to Marlboro Brook, it also enables investigation of the potential for off-site contaminant migration and characterization of groundwater quality before the groundwater discharges to the wetland area north of the site and adjacent to the brook.

Well E3-P37-M03 is located near the northeastern corner of Building T106, between the edge of the building and Old Marlboro Road. The monitoring well was screened across the water table at an interval 10 to 20 feet BGS. The well's location allows monitoring of the groundwater pathway and any potential contaminant plumes migrating from the former UST location along the eastern edge of Building T106 from other portions of the site in general. The location also enables characterization of groundwater quality before the groundwater discharges to the wetland area north of the site and adjacent to the brook.

#### 2.4 TOPOGRAPHIC SURVEYS

Topographic surveys were conducted at the Annex to determine surface water drainage pathways, and to provide a base map of the site. Surveys were performed by E & E's subcontractor, Golden Land Survey of Plymouth, Massachusetts. Each item was located to an accuracy of  $\pm 3.0$  feet on the Massachusetts State Plane Coordinate System (NAD27). All elevations were determined to an accuracy of  $\pm 0.05$  feet, referenced to the National Geodetic Vertical Datum of 1929 (USATHAMA 1987). Results of the topographic survey completed at the site are shown on the Plate at the end of this report.

#### 2.5 WATER LEVEL MEASUREMENTS

Water level measurements were used at the site to calculate groundwater elevations and hydraulic gradients, and to determine general and site-specific groundwater flow at the Annex. Measurements were made on the site on 13 September and 3 December 1993. Water elevations were generally higher on 3 December and reached a maximum of 195.73 feet above mean sea level (AMSL) at monitoring well E3-P36-M01. However, the minimum water elevation was also recorded on 3 December with a reading of 172.78 feet AMSL at

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monitoring well OHM-BW-1. The depth to water ranged from 10.27 feet BGS at well E3-P36-M02 to 17.38 feet BGS at well OHM-BW-1. These depths were both recorded on 3 December 1993.

Complete data on water level measurements are presented in Appendix C and were used to develop the understanding of groundwater contours and flow presented in Section 3.

## 2.6 AQUIFER TESTING

Aquifer testing consisted of hydraulic conductivity tests (slug tests) used to determine the rate of groundwater flow, the transport rate of contaminants within the groundwater, and the capacity for the zone of saturation to conduct water by calculating the hydraulic conductivity at the site. The tested wells at the Annex sites were grouped into four geographical areas. Site A12/P36/P37 was part of the "Southern Area of the Annex", where the average hydraulic conductivity was found to be 0.00583 feet per minute, the second lowest value of the four geographical areas. The average transmissivity was calculated to be 0.03031 square feet per minute, which was also the second lowest value of the four geographical areas. Slug tests were performed at monitoring wells E3-P36-M01 through E3-P36-M03, and E3-P37-M01 through E3-P37-M03, between 5 and 9 August 1993. Complete results from this testing are presented in Appendix G and were used to develop the understanding of groundwater at the site presented in Section 3.

#### 2.7 FIELD SAMPLING

## 2.7.1 Building Wipe Sampling in Building T104

Ten wipe samples were collected from locations on the floor in Building T104 near existing equipment or near likely locations of removed equipment that were considered potential sources of PCBs. Samples were taken in clean room No.1 near what appeared to be a solid-state transformer (E3-P36-I01) and from two floor areas near equipment pads (E3-P36-IO2 and IO3) that may have formerly contained electrical equipment. Samples were taken in the mechanical area beneath a row of condenser-like frequency filterettes (E3-P36-I04), near what appeared to be another solid-state transformer (E3-P36-I05 and I06), beneath one of the building compressors (E3-P36-I07), and beneath the heating oil tank (E3-P36-I08). Samples were taken beneath electrical conduit (E3-P36-I09) and a vapor condenser (E3-P36-I10) in clean room No.2. The selection of these points was based on a building survey conducted to identify potential sources of PCBs. The building survey conclusions were that the most likely existing potential PCB sources were the rows of frequency filterettes attached to each clean room, and the compressors. The wipe sampling locations are identified on Figure 4-1.

## 2.7.2 PCB Field Screening of Soils

Field testing of soil from surface and subsurface soil borings in the vicinity of the PCB spill/remediation area was conducted using the ENSYS PCB RISc Soil Test System. The system is based on an immunoassay/photometric detection method developed to qualitatively distinguish with 95 percent confidence samples that are PCB-free or have

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concentrations greater than 1 ppm. The system control is established through the use of 1 ppm and 10 ppm standards.

The procedure consists of three phases. Phase 1, Preparation and Extraction of the Sample, involves the weighing, extraction, and filtration of each sample to be tested. Phase 2, Sample and Standard Preparation, involves the quantitative dilution of the samples and standards to be used. Phase 3, The Immunoassay, entails incubation, enzyme addition, color development, and photometric measurement of the results. The detection limits of the analysis are based on the types of PCBs present and are shown in Appendix F in Table F-1. The presence of PCBs is determined by comparing the photometer reading of the standard to that of the samples at two dilution levels. Since an inverse relationship exists between PCB concentration and color intensity with this method, the lighter the color the higher the concentration of the PCBs. Accordingly, readings of negative or zero indicate the presence of PCBs. When tested at two different solution concentrations, the relative concentration of the PCBs is determined qualitatively.

For the investigation of the PCB spill/remediation area, samples from four borings (E3-A12-B01/B02/B03/B04) were screened using the ENSYS PCB RISc Test System at two depths. Similarly, field screening was performed for 20 surface soil samples (E3-A12-S01 through S20). All of the boring samples were then sent to the laboratory for confirmatory analysis. Based on field screening results that indicated the presence of PCBs above 10 ppm in five surface soil samples, two of these five, E3-A12-S02 and E3-A12-S03 were sent to the laboratory for confirmatory analysis. The results of the field screening and the laboratory analysis are discussed in Section 4.2 and the field screening data are presented in Tables 4-2 and 4-3.

#### 2.7.3 Groundwater Sampling

Groundwater samples were collected in September and December, 1993 from the six wells located at the site and analyzed for TCL organics, TAL metals, and TPHC. The procedures for sample collection described in Volume I, Section 3 were followed. Filtered samples were collected from each well utilizing a 0.45 micron filter and analyzed for TAL metals.

## 2.7.4 Surface Soil Sampling

Twelve samples (E3-P36-S01 through S12) were collected in August, September, and December 1993 from areas surrounding Building T104 to characterize surface contamination due to past activities at the site. The samples were collected from areas with obvious discoloration and stressed vegetation, or areas lying in surface drainage channels. At each of the 12 locations, an additional sample was collected and sent for TOC analysis. The samples will help characterize the nature of the surface soils in the area and assess the possibility that the soils are potential sorption sites for contamination. As a result of quality assurance/quality control (QA/QC) protocols approved under the Quality Assurance Project Plan (QAPjP), E & E recollected samples from E3-P36-S10 and E3-P36-S12 in September and December, respectively, and analyzed for base-neutral acid extractables (BNAs). Six

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additional surface soil samples (E3-P36-S13 through S18) were collected in April 1994 to help further assess the extent of PCB and TPHC contamination in soils around Building T104.

Twenty surface soil samples (E3-A12-S01 through S20) were collected from areas adjacent to and downgradient of the past PCB spill/remediation area located east of Building T104. The samples were collected from areas that had obvious soil discoloration, stressed vegetation, or were lying within surface drainage channels. All samples were field screened using the ENSYS PCB RISc Soil Test System described above. In addition, two samples with positive field screening hits above 10 ppm were sent to a laboratory for confirmation analysis. E & E QAPiP requirements resulted in rejection of the original soil analyses for E3-A12-S02 and E3-A12-S03. Samples were subsequently recollected from these two sample points.

Six samples (E3-P37-S01 through S06) were collected from areas surrounding Building T106 to investigate whether there was surface contamination due to past activities at the site. The samples were collected from areas that had obvious discoloration or stressed vegetation or were situated in surface drainage channels. At each of the six locations, an additional sample was collected and submitted for TOC analysis. The samples will help in characterizing the nature of the surface soils in the area and assessing the potential for sorption of contaminants by the soil.

# 2.7.5 Subsurface Investigation, Soil Sampling, and Septic Tank Sampling

Two exploratory pits were excavated at Site P36. The first pit was excavated to confirm that the 10,000 gallon UST located on the east side of the building had, in fact, been removed. This was confirmed. No petroleum odors or discolored soil were observed in the excavated area. No elevated readings were detected with the organic vapor analysis (OVA). The second pit was excavated to the south of the building to locate the blow-down box and the junction box for the leach field, which were indicated on blueprints of Building T104. The blow-down box collects moisture from heating and cooling systems and was confirmed to be underground at a depth of 3 feet approximately 25 feet south of the building. The blowdown box at Building T104 is connected by a pipe extending 30 feet southeast to a dry well located at ground surface at a corner of the fence line. No odors or discoloration were observed in the excavation, and no elevated readings were detected on the OVA. Excavation at this pit also located the junction box for leach field. The junction box is located 10 feet west of the blow-down box. Although the leach field was not uncovered due to breakdown of the backhoe, the piping from the junction box extends south, where the leach field is likely to be located.

Based on the exploratory pit findings, one test pit was excavated in April 1994 in the Building T104 leach field area. The test pit (E4-P36-P01) was excavated to a depth of 4 feet BGS, across a length of approximately 20 feet, with a width of approximately 2 feet. The leach pipes were broken during the excavation of this test pit. Subsurface soil samples were collected from the soil beneath each of the three leach field pipes to identify if any contaminants may have migrated via the septic system in Building T104. The excavation was then backfilled.

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A sludge sample (at E4-P36-P02) was collected in April 1994 from the Building T104 septic tank. Three feet of soil was excavated to uncover the top of the septic tank. The tank was opened and the sludge sample was collected from the solid material at the top of the tank. The tank had sludge up to just under the cover. The cover was placed back on the tank after sample collection and the excavation was backfilled.

Six samples were collected, two from each of three borings (E3-P36-B01/B02/B03) located near Building T104. The samples were collected from different depths in each boring. The samples provide data to investigate subsurface contamination and characterize the nature of subsurface soils in the area. Boring E3-P36-B01 was completed in the paved area west of Building T104. Samples were collected from split spoons at depths of 9 to 11 feet BGS and 14 to 16 feet BGS. Boring E3-P36-B02 was completed along the northern edge of Building T104 and sampled with the use of split-spoons at depths between 4 to 6 feet BGS and 9 to 11 feet BGS. The third boring, E3-P36-B03 was completed along the southern edge of Building T104 and sampled using split spoons at depths between 4 to 6 feet BGS and 9 to 11 feet BGS.

Eight samples, two from each of four borings (E3-A12-B01/B02/B03/B04), were collected to investigate subsurface contamination in the area immediately surrounding the past PCB spill/remediation area. The borings were placed crossgradient and downgradient of the soil removal area. Eight samples were collected, as each of the four borings was sampled at two different depths. In addition to full laboratory analysis, each of the eight samples was also screened in the field using the ENSYS PCB RISc Soil Test System. One geotechnical sample was collected at a depth of 0 to 2 feet BGS in boring E2-A12-B03 and sent for grain size and Atterberg limits analyses. The geotechnical sample provides data on the nature of the subsurface soils in the area and their influence upon contamination migration in the groundwater pathway. The methods used and the field screening results are discussed in PCB Field Screening above.

Six samples were collected, two from each of three borings located near Building T106. The samples were collected from two different depths in each boring. The samples provide data to investigate subsurface contamination and to characterize the nature of subsurface soils in the vicinity of Building T106. Boring E3-P37-B01 was completed in the cleared area southwest of Building T106. Samples were collected from split-spoons at depths between 9 to 11 feet BGS and 14 to 16 feet BGS. Boring E3-P37-B02 was completed near the southeastern corner of Building T106 and sampled using split-spoons at depths between 9 to 11 feet BGS and 14 to 16 feet BGS. The boring allowed investigation of the presence of any residual contamination in the subsurface soils due to past activities in the cleared area south of Building T106. The third boring, E3-P37-B03 was completed in the center of the southern edge of Building T106 and sampled at depths between 9 to 11 feet BGS and 14 to 16 feet BGS. The boring, like E3-P37-B02, allowed investigation of the presence of any residual contamination in the subsurface soils due to past activities in the cleared area south of Building T106. As a result of the QA/QC protocols approved in the QAPjP, E & E recollected samples from boring E3-P37-B02 in December 1993 at depths between 9 to 11 feet BGS and 14 to 16 feet BGS and analyzed them for BNAs only.

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During subsurface soil sampling, geotechnical samples were collected from the saturated zone in each monitoring well and sent for grain size analysis. This physical analysis provides data on the types of subsurface soils at the site and their potential to affect rates of movement of groundwater. In addition, during monitoring well installation, a sample was collected from the screened interval in each well and sent for TOC analysis. The samples yield further data on the subsurface soils at the site, which aids in assessing the potential for sorption of contaminants in the groundwater pathway.

## 2.7.6 Surface Water and Sediment Sampling

Surface water and sediment samples were collected from three locations to characterize the water quality and sediments of Marlboro Brook both within Annex property and at the boundary and also to assess the potential for off-site contaminant migration through the surface water pathway from the site areas around Building T104, the PCB spill/remediation area, and Building T106. The sediment samples were analyzed for TOC and grain size (all samples), as well as Atterberg limits (only at E3-P37-D03). The surface water/sediment sample location E3-P37-D01 lies on the western edge of the pond and wetland area, which is approximately 100 feet northeast of the intersection of Diagonal Road and Old Marlboro Road. The surface water/sediment sample locations E3-P37-D02 and E3-P37-D03 are both downstream of location E3-P37-D01. Sediment samples at E3-P37-D02 and E3-P37-D03 monitor levels of contamination in the stream and sediments as Marlboro Brook flows off the Annex before converging with Hop Brook. To further characterize sediment and water quality as Marlboro Brook leaves Annex property, sediment sample location E3-P37-D03 was resampled in late September 1993 for explosives, phosphates, herbicides, and organophosphorus pesticides.

#### 2.8 ECOLOGICAL ASSESSMENT

The site is located in a developed area along Old Marlboro Road in the southern portion of the Annex. In July 1993, E & E conducted a field survey which included identification of the vegetation cover-types, wetland boundaries, and the plants and animals in the general vicinity of the site. Based on this field survey, five different cover types were identified: four upland plant communities and one wetland community.

## 2.8.1 Ecological Characterization

An ecological characterization of the A12/P36/P37 site was conducted to provide information for the baseline risk assessment (human health evaluation and ecological evaluation). The primary objective of the characterization was to identify and evaluate existing aquatic, terrestrial, and wetland communities. Other objectives included mapping and describing plant communities within the site, observing wildlife species present in the vicinity of the site, identifying and evaluating significant ecological resources that could be impacted by contamination from the site, and noting evidence of plant or animal stress that may be a result of site contamination. Emphasis was placed on sensitive environments or species that may come in contact with site contamination, such as State- or federally-designated wetlands, critical habitats, and species of concern. Based on E & E's preliminary evaluation of

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available information on site ecology and a site visit, conducted 22 June 1993, the ecological resources potentially impacted by the site were identified for further characterization. These resources include aquatic and wetland communities in the vicinity of the site, as well as terrestrial vegetation and wildlife species living on or in the vicinity of the site.

The methodology for the ecological surveys including wetland delineation and functional assessment, cover-type mapping, agency contacts, literature review, and wildlife use of the site are provided in Volume I (Section 3.1.8).

## 2.8.2 Rapid Bioassessment (MB-2)

Rapid bioassessment (RBA) is a method used to determine the biological condition of a stream or river, and whether or not the system is potentially impaired from its natural state. Collected samples are compared to a background stream reference point. An evaluation is then made as to the impairment, or lack thereof, of the stream from input within the watershed. The biological stream can then be marked as one of the following: non-impaired, moderately impaired, or severely impaired, where impaired is identified as a reduction in species comparable to the best situation to be expected within an ecoregion. Assessments are also made as to stream flow, bottom characterizations and riparian vegetation descriptions.

RBA station MB-2 (Marlboro Brook) is located off of Annex property downstream from a ponded area of Marlboro Brook before it crosses Surry Lane. This location is downstream of several residential properties, Moore Road, and the remains of an old stone foot bridge. This location was surveyed and sampled by an E & E field team between 24 and 26 May 1993. Samples collected at this station were compared to RBA reference station TB-1 (Taylor Brook) located in an upgradient area on the northern part of the Annex. Results of RBA station MB-2 indicated that lower Marlboro Brook system at the sample point appears to be non-impaired relative to reference station TB-1. It should be noted that the stream at TB-1 receives some drainage from the Digital Equipment Corporation parking lot, and the stream at MB-2 receives some drainage from along Moore Road off-site. Further descriptions of the procedures and results of the RBA can be found in Volume IV, Appendix L.

## 2.9 QUALITY ASSURANCE/QUALITY CONTROL RESULTS

#### 2.9.1 Site Data Review Procedures

This section provides a summary of the results of the QA/QC review performed using the protocol described in Volume I.

Data for the site were evaluated for usability by reviewing laboratory and field QC sample data for contamination possibly introduced into field samples by either sampling or analysis procedures. First, method blanks were reviewed for each analyte in the 262 lots associated with Watershed 2, followed by trip blanks and then rinsate blanks. Following consideration of laboratory and field QC blank samples data, laboratory flagging codes and USAEC data qualifiers were evaluated with laboratory control charts for each lot and sampled for quality assurance problems. Analytical results were then reviewed for precision through

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consideration of the relative percent difference (RPD) between each sample/duplicate pair and matrix spike/matrix spike duplicate (MS/MSD) sample set. It is important to note, as discussed in Appendix F, that method blank results for TAL metals were not used to qualify soil or sediment sample data because the USAEC Repository Standard Soil had low levels of metals that do not correspond to the native soils surrounding the Annex. Therefore, only rinsate blank results were used to qualify the results for the metals in soil or sediment samples based on blank contamination.

Following is a discussion of samples for each of the three previous investigation sites within the RI site affected by QA/QC evaluation. Samples with contamination found in the blank were qualified either with a "B" usability code for "present in the blank" or a "K" usability code for a result-biased high. Samples considered to have quality assurance problems were qualified with either an "L" usability code for a result-biased low or "R" for rejected. Samples exhibiting either high or low recoveries were qualified with a "J" usability code for estimated or "R" for rejected. Appendix F provides a summary of QC data for method blanks, trip blanks, rinsate blanks, field duplicate samples, and MS/MSD samples.

## 2.9.2 Data Useability

## 2.9.2.1 Site A12 — PCB Spill/Remediation Area

Only five analytes were found in the method blanks associated with samples from Site A12. For the two surface soil samples SXA12021 and SXA12031, endrin, endosulfan sulfate. and heptachlor epoxide were qualified as found in the blank. Dieldrin was also found, but only in the method blank for SXA12021.  $\alpha$ -endosulfan was also found, but only in the method blank for sample SXA12031.

There were no other QA/QC issues for Site A12.

## 2.9.2.2 Site P36 — Former Raytheon Building T104

#### For samples collected prior to April 1994

Blank contamination was observed for 14 analytes in 38 samples. Analytes found in the method blanks were: bis(2-ethylhexyl)phthalate and methylene chloride from common laboratory contamination, aluminum, lead, and zinc from either analysis reagents or processing of the samples, and potassium and sodium from the standard water matrix. Analytes found in the rinsate blanks included: aluminum, bis(2-ethylhexyl)phthalate, cadmium, iron, heptachlor, lindane, sodium, lead, antimony, TPHC, and zinc all attributable to the same sources as discussed previously. In all cases, sample data were qualified as found in the blank.

There were 17 samples for which sample data were biased high due to blank contamination. Analytes of concern included: bis(2-ethylhexyl)phthalate, butylbenzyl phthalate, cadmium, potassium, sodium, lead, antimony, and zinc.

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A review of control charts submitted by the laboratory revealed that for lot AART, five surrogates had low recoveries. As a result, this BNA lot was qualified as biased low for all analytes.

On review of duplicate pair precision data associated with Site P36, only  $\alpha$ -chlordane and DDE in the duplicate sample pair (SX3601X1/SD3601X1) were qualified as estimated due to exceedences of RPD precision criteria.

MS/MSD precision criteria were exceeded for barium and magnesium in MS/MSD sample MXP36011 and for nickel, antimony, and selenium in MS/MSD sample BX360101. As a result, 10 samples from Site P36 were qualified as estimated for one or more of these analytes.

There were no other QA/QC issues associated with Site P36.

# For samples collected in April 1994

Consideration of quality control sample results revealed the presence of only three analytes in the method blanks associated with five samples at levels considered to affect data. These were beryllium, zinc, and acetone present due to common laboratory solvents or analysis reagents. In these cases, the sample was qualified with a "B" for being found in the method blank.

A review of laboratory quality assurance data revealed that three analytes may have been biased low in nine samples due to low recoveries. The three analytes were selenium, PCB-1254, and PCB-1260, and affected samples were assigned the data usability code of "L".

Thirteen analytes found in one or more of 21 samples were considered estimated because the results were found to be between the instrument detection limit and the method detection limit. These analytes were antimony, calcium, cobalt, magnesium, mercury, acenapthene, butylbenzyl phthalate, naphthalene, phenanthrene, o-xylene, m- or p-xylene, carbon disulfide, and TPHC. In these cases, the analytes were assigned the data useability code of "J" for estimated.

There were two analytes (PCB-1254 and PCB-1260) in five samples which were assigned the data useability code of "C" to indicate positive confirmation of analytical results.

There were no other QA/QC issues for the samples collected in April 1994 at Site P36.

## 2.9.2.3 Site P37 — Building T106 UST

Site P37 had 34 samples affected by one or more of the 19 analytes found in either the method or rinsate blanks associated with Site P37. Specifically, for method blanks this included acetone,  $\alpha$ -endosulfan, aluminum, aldrin, bis(2-ethylhexyl)phthalate, methylene chloride, diethyl phthalate, endosulfan sulfate, potassium, lindane, sodium, lead, and zinc; for

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rinsate blanks this included aluminum, bis(2-ethylhexyl)phthalate, cadmium, methylene chloride, carbon disulfide, iron, heptachlor, lindane, manganese, sodium, lead, antimony, and zinc. In all cases, sample data were qualified as found in the blank.

There were also 21 samples for which data were qualified as biased high because of blank contamination. Analytes affected in one or more samples included beryllium, cadmium, endrin, endosulfan sulfate, potassium, lindane, sodium, TPHC, and zinc.

A review of laboratory control charts revealed four lots for which data were biased low due to low surrogate recoveries. In total, 68 analytes from one or more of nine samples (DXP37011, DXP37021, DXP37031, MDP37011, MRP37021, MXP37011, MXP37021, SX3705X1, and SX3706X1) were affected.

Only TOC exceeded RPD precision criteria for duplicate pairs. As a result, only samples BX370302 and BD370302 were qualified as estimated.

There were 13 samples for which one or more of 9 analytes were qualified as estimated due to low MS/MSD recoveries. Analytes of concern included: α-endosulfan, arsenic, barium, calcium, dieldrin, endrin, manganese, mercury, and DDT.

No other QA/QC issues at Site P37 were observed.

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#### 3. SITE PHYSICAL CHARACTERISTICS

Field activities described in Section 2 were used to better characterize the physical setting of the site, including the site's geology, soils, groundwater hydrology, topography, and ecology. Each of these physical characteristics are discussed in this section. Broader regional conditions are described in Volume I, Section 2.2.

#### 3.1 GEOLOGY

Site A12/P36/P37 is located on the site of a low hill of glacial till identified as a ground moraine by Hansen (1956) and described as a drumlin by Perlmutter (1962), which slopes gently to a surrounding outwash plain. This discrepancy is an issue of morphology and regardless of the mode of formation, the geologic material of which the hill is composed remains the same. A layer of outwash material covers the clayey silt and gravel till across the area. This layer of outwash material gradually thickens toward the east and the wetlands area to the east-northeast from a thickness of 6 feet to greater than 21 feet thick. Bedrock was not encountered during any drilling activities at the site; however, based on the interpretation of a seismic refraction survey conducted in May 1993, it appears that bedrock topography is subparallel to surface topography. Bedrock elevations are interpreted to range from 170 feet AMSL northwest of Building T104 to 130 feet AMSL east of Building T106, or approximately 40 to 60 feet BGS. The underlying bedrock probably consists of quartz diorite and gabbrodiorite (Hansen 1956).

## 3.2 SOILS

Soils under the site are of the Merrimac, Paxton, and Swansea series (OHM 1992), but note ecological characterization, Section 3.5.1. Paxton soils develop from till on the drumlins and moraines. The Paxton is a well drained loam. This soil has a clay content ranging from 3 to 12 percent, and a permeability of from 0.6 to 2 inches per hour (4 x 10⁻⁴ to 1.4 x 10⁻³ centimeters per second (cm/sec)) at up to 26 inches in depth. Below this depth, compacted tills are encountered with permeability of less than 0.2 inches per hour (4.4 x 10⁻⁴ cm/sec). Organic content ranges from 2 to 5 percent. The Merrimac soils associated with the outwash deposits are very well drained and sandy. Clay content ranges from 3 to 7 percent in the first 15 inches, but is less than 4 percent from 15 to 60 inches. Permeability ranges from 2 to 6 inches per hour (1.4 x 10⁻³ to 4 x 10⁻³ cm/sec) from 0 to 22 inches of soil, and up to 20 inches per hour (1.4 x 10⁻² cm/sec) from 22 to 60 inches of soil. Organic content ranges from 1 to 5 percent in the first 15 inches of soil. The Swansea (muck) is a very poorly drained soil developed in organic deposits of the swamps, bogs and marshes associated with the low-lying areas scattered throughout the Annex. Clays are found only in the bottom reaches (26 to 60 inches) and can range between 1 to 5 percent. Permeability of this highly organic material runs between 0.6 to 6 inches per hour (4 x 10⁻⁴ to 4 x 10⁻³ cm/sec) to a depth of 26 inches, and greater than 20 inches per hour (1.4 x 10⁻² cm/sec) from

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26 to 60 inches of soil, which is below most of the organic muck and peat. Organic content is high (greater than 50 percent) within the first 9 inches of soil.

## 3.3 GROUNDWATER HYDROLOGY

The highly permeable soils over much of the Annex allows for high recharge rates. The average for the Annex south of Hudson Road was calculated at half the precipitation, which averages 42 inches per year. At Site A12/P36/P37, however, recharge is expected to be somewhat less than 21 inches per year due to the tight till beneath most of the site, the relatively steep topography, and the high percentage of impermeable cover (pavement and buildings). The shape of the underlying water table is the result of the balance between infiltration and groundwater discharge to surface water. The known groundwater discharge area is Marlboro Brook located approximately 200 feet northeast of the site.

Water level measurements collected from six wells located at the site show that groundwater flow reflects topography, sloping west-southwest to east-northeast. Water level measurements are presented in Table 3-1. The hydraulic gradient from the west side of Building T104 to Marlboro Brook is approximately 0.024 feet/foot. Hydraulic conductivity across the site ranges from 0.834 feet per day to 23.85 feet per day. In general, hydraulic conductivity is higher in the monitoring wells screened entirely in outwash material on the eastern side of the site versus wells screened partially in outwash material and partially in till on the western side of the site. Groundwater contours are shown on Figures 3-1 and 3-2.

## 3.4 TOPOGRAPHY AND SURFACE WATER DRAINAGE

Elevations at the site range from 210 feet AMSL west of Building T104 to 175 feet AMSL at Marlboro Brook northeast of the site. Surface water flow follows topography, flowing down the hillside toward Marlboro Brook. Pavement and buildings at the site enhance the volume of direct runoff to the stream. Marlboro Brook flows east from the site, ultimately draining into Hop Brook, approximately 2,500 feet downstream. The surface water elevation at SG19 in Marlboro Brook, 300 feet east of the site, was measured at 175.4 feet AMSL on 27 April 1994.

## 3.5 ECOLOGICAL CHARACTERIZATION

The purpose of the ecological characterization is to identify, map, and describe the upland, wetland and aquatic ecosystems that occur in the vicinity of the site. A major objective of this ecological characteristic is to determine whether or not significant ecological resources on the site or in its proximity could be impacted by site contaminants. These significant resources include jurisdictional wetlands and other sensitive environments; State or Federal rare, threatened, or endangered species; and economically or recreationally important fisheries or wildlife. Observations of physically stressed plants and animals, the absence of common species known to be sensitive to the type of contaminants found at the site, or any other signs indicating effects attributable to site contaminants are also discussed in this section. Information used to write this section was collected during an ecological field survey

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		VATIONS FOR DF A12/P36/P37
Well	9/13/93	12/3/93
E3-P36-M01	195.49	195.73
E3-P36-M02	185.09	186.59
E3-P36-M03	177.25	177.57
E3-P37-M01	182.36	181.98
E3-P37-M02	176.93	176.99
E3-P37-M03	175.15	173.24
OHM-BW-1	173.19	172.78

Source: Ecology and Environment, Inc., 1994.

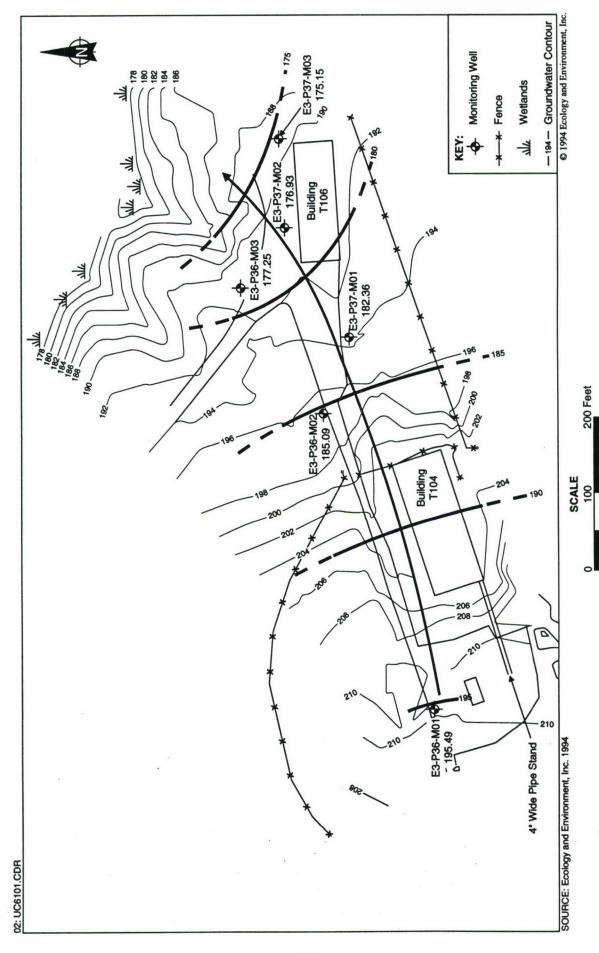


Figure 3-1 GROUNDWATER CONTOURS AND FLOW INTERPRETATION BASED ON 13 SEPTEMBER 1993 MEASUREMENTS

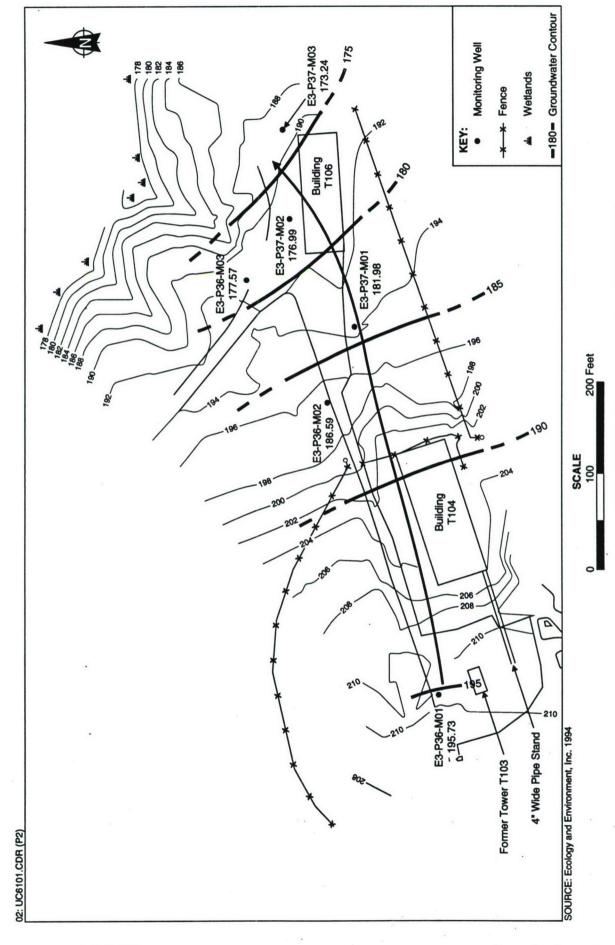


Figure 3-2 GROUNDWATER CONTOURS AND FLOW INTERPRETATION BASED ON 3 DECEMBER 1993 MEASUREMENTS

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conducted by E & E biologists on 22 June 1993. The methodology used during the site survey is referenced in Section 2.9 of this report.

# 3.5.1 Cover Type Descriptions for Upland Communities

A total of five distinct cover types were identified within the area of the A12/P36/P37 site. Four of these cover types represented upland plant communities and one was a wetland plant community. No areas of dead trees or other evidence of physical stress were observed during the June survey. The boundaries of these cover types are depicted in Figure 3-3 and the plant species identified within the area are listed in Table 3-2. Volume I, Section 2, Tables 2-1 through 2-4 list common scientific names of birds, mammals, amphibians, and reptiles that were observed and/or are likely to occur at the Annex based on range maps (DeGraff and Rudis 1987). Table 2-5 in Section 2, Volume I lists the Species of Concern known to occur at the Annex. Each cover type is described in terms of plant species composition, vegetation structure, edaphic condition and land use. The value of each cover type to wildlife is also discussed.

New England Army Corps of Engineers wetland delineation data forms were completed for each wetland cover type and are provided in Appendix K. The wetland cover types discussed below meet the three criteria (i.e., hydrophytic vegetation, hydric soils, and wetland hydrology) necessary to be considered federally regulated jurisdictional wetlands. Data forms were completed to evaluate wetland functions and values. Table 3-3 lists the wetlands function evaluation rating for the A12/P36/P37 wetland area. A discussion of the methodology employed to determine these values is referenced in Section 2.9.1 of this report and discussed in detail in the Volume I, Section 3.1.8.1.

# Cover Type 1: Open Water Wetland (POW)

Cover type 1 is part of a narrow open-water emergent wetland located approximately 300 feet north and downgradient of the site (Figure 3-3). The southern end of this wetland has been dammed to form a small pond or widening of Marlboro Brook. The United States Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) map classifies this area as a seasonally saturated palustrine emergent wetland (PEME). Being located downgradient from the site, this wetland and Marlboro Brook are likely recipients of surface runoff from the site.

In general, the vegetation is concentrated along the edges of the pond. The overstory is very sparse and consists of scattered hemlock. The understory is dominated by herbaceous vegetation but also includes speckled alder and red maple saplings. Herbaceous and emergent plants such as yellow water lilies, cattails (concentrated in the northern end of the pond), jewelweed, sensitive fern, sedges, slender-leaved iris, boneset, skunk cabbage, and bulrushes comprise the dense herbaceous layer. Many snags were observed in the open pond area.

The soil underlying the area near the wetland is Montauk muck, a very poorly drained fine silt loam (*Middlesex County Massachusetts Interim Soil Survey Report* 1991). Characteristics observed during the soil analysis included a low matrix chroma (black muck)

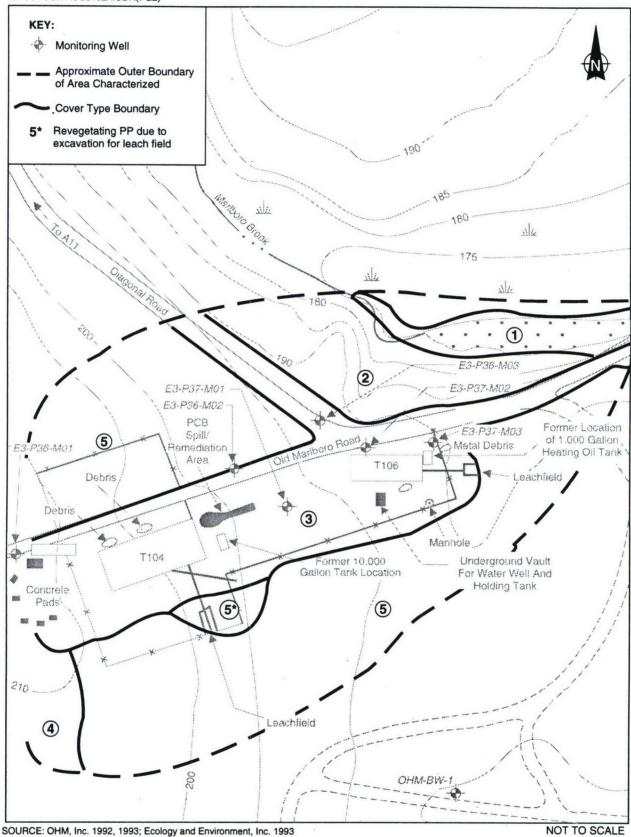


Figure 3-3 COVER MAP FOR AREAS NEAR T104, T106, AND PCB SPILL/REMEDIATION AREA (SITE A12/P36/P37)

recycled paper ecology and environment

	DENTIFIED	RI SITE
Lable 3-2	COMPOSITION OF PLANT COMMUNITIES IDENTIFIED	IN THE GENERAL VICINITY OF THE RI SITE

Cover Type	Stratum	Vegetation Density ^a	Species ^b
Open Water Wetland (POW)	tree sapling shrub herb	sparse sparse sparse moderate	hemlock specked alder, red maple none jewelweed, water lily, sensitive fern, slender-leaved iris, boneset, cattails, skunk cabbage
2. Mixed Forest	tree sapling shrub herb	dense dense dense sparse	white pine red maple, American chestnut, white oak, red pine low blueberry, ironwood Canada mayflower, wood fern, sassparilla, starflower, bracken fern
3. Open Disturbed Area	tree sapling shrub herb	sparse sparse moderate sparse	cottonwood gray birch, fire cherry bush clover, asters, goldenrods, whorled loosetrife, sweet white clover, cinquefoil skunk cabbage, cinnamon fern, royal fern, jewelweed, sphagnum moss, highbush blueberry
4. Oak Forest	tree sapling shrub herb	moderate dense dense moderate	red oak, scarlet oak red maple, red oak, American chestnut, white pine, scarlet oak low blueberry, sweetfern grasses, partridge berry, bracken fern, wood pine
5. Red and White Pine Plantation	tree sapling shrub herb	dense moderate moderate sparse	red pines, white pine American chestnut, red maple, red pine, white pine low blueberry pink ladyslipper, bracken fern, mosses, partridge berry

a Sparse = 0 to 30 percent area cover in the stratum.

Moderate = 31 to 65 percent area cover in the stratum.

Dense = 66 to 100 percent area cover in the stratum.

b If a dominant species was observed, only the dominant species was included in the list below.

Source: Ecology and Environment, Inc. 1994.

Table 3-3
WETLAND FUNCTIONS EVALUATION RATING
FOR THE A12/P36/P37 SITE WETLAND AREA

Function	Open Water Score	Wetland Value
Biological	74	Moderate
Hydrological Support	29	Moderate
Groundwater Discharge	47	Moderate
Floodwater Storage	79	Moderate
Water Quality Maintenance	61	Moderate
Cultural and Economic	25	Low
Recreation	35	Moderate
Aesthetic	37	Moderate
Education	18	Moderate

Source: Hall and McGee 1985.

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with no mottles. Wetland hydrology indicators observed during the site survey included areas of inundation, water marks on trees and shrubs, the presence of snags, and soil saturation in the upper 12 inches.

Emergent wetlands are of high value to wildlife. Such wetlands provide drinking water, food, breeding areas, and shelter for both permanent residents as well as animals that regularly visit from other habitats. A variety of amphibians, reptiles, waterfowl, fish, piscivorous birds, and raptors can be found in this type of community. In addition, the abundant emergent vegetation provides cover and food for may wildlife species that frequent this habitat. During the June site survey a painted turtle was observed in this area.

Of the nine wetland functions evaluated in this wetland during the field survey, one was rated "low" and eight were rated "moderate" (see Table 3-3). The "moderate" ratings were at the low end of the range. Therefore, this wetland is expected to support low to moderate diversity and abundance of aquatic and terrestrial species; moderately store and release storm flood waters; and moderately improve water quality.

# **Cover Type 2: Mixed Forest**

Cover type 2 is located in the northeastern portion of the site, between Diagonal Road and Moore Road and the emergent wetland of cover type 1 (Figure 3-3). The dense overstory is dominated by white pine ranging from 4 to 16 inches in diameter at breast height (DBH) and also includes white spruce, red oak, and red pine. The understory is covered with a thick organic layer of needles. Scattered overstory saplings, American chestnut, low blueberry, and ironwood grow in the area. The herbaceous layer includes Canada mayflower, wood fern, sassparilla, various grasses, bracken fern, and starflower.

Despite the proximity to Diagonal and Moore Roads, this area is of moderate to high value to wildlife. Cover type 2 combines an abundance of food, cover, and edge habitat and is adjacent to the open water emergent wetland and Marlboro Brook of cover type 2. Consequently, this area is likely to support and be utilized by a variety of wildlife species. Pine seeds, acorns, buds, flowers, and twigs, are a source of food for many species of songbirds, upland gamebirds, small mammals, and deer (Martin et al. 1951). The thick mat of leaves provide shelter and food for many species of insects, amphibians, and reptiles. Finally, deer and rabbit will use this area for cover particularly in the winter. During the June site survey, a chickadee and a red squirrel were observed within the boundaries of cover type 2.

## Cover Type 3: Open Disturbed Area

Cover type 3 is associated with the site itself, and includes the relatively level area around the abandoned Buildings T106 and T104 (Figure 3-3). There is no overstory vegetation within this cover type. The eastern portion of the area consists of herbaceous plants such as asters, goldenrods, whorled loosestrife, white sweet clover, various grasses, and cinquefoil. The western portion of this disturbed area is less open and is dominated by gray birch and fire cherry saplings. Low blueberry, sweetfern, red oak, paper birch, big

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tooth aspen, scotch pine, and white pine shrubs/saplings also occur in this western portion of the site. Scattered cottonwood trees grow along the edges of cover type 3.

Open disturbed areas are of relatively low value to wildlife. Lack of cover and plant diversity combined with disturbance from activity on the roads and near buildings discourage many animals. However, this area does provide seeds and berries that may be consumed by several species of songbirds and small mammals.

# Cover Type 4: Oak Forest

This cover type is located on the western portion of the site adjacent to cover type 3 described above (Figure 3-3). The dominant tree species in the overstory are red oak ranging from 4 to 16 inches DBH and scarlet oak ranging from 12 to 26 inches DBH. Scattered red maple also grow here. The relatively dense understory consists of overstory saplings, sweetfern, and low blueberry. A heavy mat of leaf litter covers the ground and limits herbaceous layer to scattered partridge berry, bracken fern, wood pine and grasses.

This forested area is considered of moderate to high value to wildlife due to its proximity to the open/disturbed area near the RI site; pine seeds, acorns, buds, flowers, and twigs, are an important source of food for many species of songbirds, upland gamebirds, small mammals, and deer (Martin et al. 1951). In addition, the thick mat of leaves provides shelter and food for many species of insects, amphibians, and reptiles. Finally, forested areas similar to cover type 4 represent valuable cover, which is used by deer and rabbits particularly during the winter. Red squirrel, ovenbirds, woodpeckers, and gypsy moths were observed within the boundaries of cover type 4 during the June 1993 site survey.

# Cover Type 5: Red and White Pine Plantation

Cover type 5, the red and white pine plantation, is located in the northern and southern edges of the disturbed area around the site (Figure 3-3). Red pines ranging from 4 to 12 inches DBH dominate in this area, but white pine, red oak, and scarlet oak trees are also present. The relatively dense understory includes low blueberry, American chestnut, and overstory regeneration. A thick layer of needles and decaying leaves covers the ground. Mosses, partridge berry, bracken fern, and pink ladyslipper comprise the sparsely vegetated herbaceous layer. No woody vines grow in this cover type.

Cover type 5 is considered of moderate to high value to wildlife; pine seeds, acorns, buds, flowers, and twigs, are consumed by many species of songbirds, upland gamebirds, small mammals, and deer (Martin et al. 1951). Many species of insects, amphibians, and reptiles are expected to use the thick mat of decaying leaves and needle for cover and food. Deer and rabbit are likely to use this area for cover particularly in the winter. In June 1993, a wild turkey was heard in the area and a red squirrel was observed by site surveyors.

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# 3.5.2 Aquatic Resources

Marlboro Brook and the emergent wetland associated with it are located approximately 400 feet north of the site. Marlboro Brook flows from northwest to south/southeast in this area. The riparian vegetation associated with the stream and the ponded area is diverse and includes yellow water lilies, cattails, jewelweed, sensitive fern, sedges, slender-leaved iris, boneset, skunk cabbage, and bulrushes (refer to cover type 1).

# 3.5.3 Species-of-Concern and State-Designated Estimated Habitats of Rare Wetlands Wildlife

The following are definitions of the four categories of species-of-concern as defined by the Massachusetts Natural Heritage Program (MNHESP, 321 CMR 10.03):

- ENDANGERED: A native species in danger of extinction throughout all or a significant portion of its range and species of plants or animals in danger of extirpation as documented by biological research and inventory.
- THREATENED: Any species of plant or animal likely to become an
  endangered species within the foreseeable future throughout all or a
  significant portion of its range and any species declining or rare as
  determined by biological research and inventory, and likely to
  become endangered in the foreseeable future.
- SPECIAL CONCERN: Any species of plant or animal which has been documented by biological research and inventory as to have suffered a decline that could threaten the species if allowed to continue unchecked or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become threatened within Massachusetts.
- WATCH LIST: Any species of plant or animal which has been documented by biological research or inventory to have suffered a decline or that occurs in such small numbers or with such restricted distribution or specialized habitat requirements that it could easily become a species of special concern within Massachusetts.

A total of 19 species of concern have been documented within approximate 1.5-mile radius of Site A12/P36/P37. Although the majority of these species were observed in the northern part of the Annex they will be discussed here because they are within migratory range of the RI site in question and could potentially be affected by site contaminants. These species include 1 federally-protected endangered species, 1 State-listed endangered species, 2 State-listed threatened species, 4 State-listed species of special concern in Massachusetts, and 11 watch-list species. These species and the approximate locations in which they were found are listed below.

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# Plant Species

A population of <u>Midland sedge</u> (*Carex mesochorea*), a State endangered plant species, was found approximately 2 miles north of the site in the northern part of the Annex (Hunt 1992). A population of a plant species threatened in Massachusetts, <u>Few-seeded Sedge</u> (*Carex Oligosperma*), was found north of the site near Patrol Road and within a 1.5-mile radius of the site (Hunt 1992).

Several Massachusetts watch list plant species are in the northern part of the Sudbury Annex: Small beggar ticks (*Bidens discoidea*), Lacegrass (*Eragrostis capillaries*), Blazing Star (*Liatris Borealis*), Red Pine (*Pinus resinosa*), and Northern Starwort (*Stellaria calicantha*) (Hunt 1992).

Grass-leaved Ladies' Tress (Spiralis vernalis), a Species of Special Concern in Massachusetts, was identified in the unmowed field in the Taylor Drop Zone located almost 2 miles north of A12/P36/P37 (Aneptek 1991). Wood Witchgrass (Panicum philadelphicum), another Species of Special Concern, was observed in the western part of the Annex within a 1.5-mile radius of the site (Hunt 1992).

# **Avian Species**

During the winter 1990, a pair of federally protected <u>Bald Eagles</u> (Haliaeetus leucophalus) was observed for two consecutive days in the trees along the forest edge of the Taylor Drop Zone, approximately 2 miles north of Site A12/P36/P37 (Aneptek 1991). The red-shouldered hawk (Buteo Lineatus), a Massachusetts watch-list species, was observed perched on a large dead oak on the western edge of the Taylor Drop Zone (Aneptek 1991). The Eastern Bluebird (Sialis sialis) and the Purple Martin (Progne subis), two Massachusetts watch-list species, were observed by residents of the Capehart housing area approximately 2,500 feet northwest of A12/P36/P37 (Aneptek 1991). In November 1993, a Great Blue Heron (Ardea herodias) and an Osprey (Pandion haliaeetus) were observed in the Puffer Pond area within a 1.5-mile radius of the RI site.

## Reptile and Amphibian Species

Spotted Turtles (Clemmy gutata), a Species of Special Concern, were found at three locations on the Annex, all within an approximate 1.5-mile radius of the RI site. Blue Spotted Salamander (Ambystoma laterale) eggs, another Species of Special Concern in Massachusetts, were noted in a vernal pool in the northern part of the Annex. A State watchlist species, Spotted Salamander (Ambystoma maculatum), was also observed in the northern part of the Annex (Butler 1992). Finally, a Blanding's Turtle (Emydoidea blandingii) was observed at the Annex within a 1.5-mile radius of the site (OHM July 1993).

## State-Designated Habitat of Rare Wetlands Wildlife

The MNHESP identifies wetland areas considered to be suitable habitats for species of rare vertebrate and invertebrate animals that use wetlands for foraging, breeding, and/or

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nesting. Although this area includes estimated State-listed habitats that are regulated under the Massachusetts Wetlands Protections Act, no such unique habitats have been identified in the general vicinity of the site (MNHESP 1992).

## 3.5.4 Discussion

The area within the site boundaries has been significantly disturbed by human activity: The area immediately adjacent to Buildings T104 and T106 has been cleared and disturbed and is of low value to wildlife. However, the forested areas surrounding the site are expected to support a diverse wildlife. Of particular importance is the emergent wetland area associated with Marlboro Brook and located approximately 400 feet north of the site.

This emergent wetland area is located downgradient of the site and could potentially be exposed to site runoff and site contaminants. Such an area is considered of high value to wildlife because it provides drinking water, food, breeding areas, and shelter for both permanent residents as well as animals that regularly visit from the nearby forested areas. During the site visit, no signs indicating the impairment of this community were observed and no effects attributable to site contaminants were noted.

Nineteen species of concern have been documented within a 1.5-mile radius of the site. However, the majority of them were identified in the northern part of the Sudbury Annex, north of Hudson Road and no species of special concern were ever documented within the boundaries of the RI site.

The areas around Buildings T104 and T106 are very sparsely populated and low in terrestrial diversity. This may have resulted from the physical disturbance (clearing and roads) at this site, or from site contaminants impacting the local terrestrial fauna and flora, or from a combination of both. The surrounding forests appeared to sustain a relatively high diversity of terrestrial wildlife suggesting that there is no current significant impact from the site beyond the site boundaries.

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#### 4. NATURE AND EXTENT OF CONTAMINATION

This section discusses the potential sources of chemical contamination associated with the site, the nature and extent of contamination indicated by field investigation and sampling efforts, and concludes by relating the sample analysis results to the potential sources. Location of sampling points are identified on the oversized site map enclosed at the back of this volume with the exception of Building T104 wipe samples, which are identified on Figure 4-1, and surface water/sediment samples which are identified on the Plate at the end of Volume I. Detections above background in groundwater sampling are noted in Table 4-1 in Section 4.2.5. Field Test Results for PCB screening are included at the end of Section 4.3 in Tables 4-2 and 4-3. Chemical summary reports for building wipe samples (Table 4-4), septic tank and field sampling (Table 4-5), surface soil sampling (Tables 4-6, 4-7, and 4-8), subsurface soil sampling (Tables 4-9, 4-10, and 4-11), groundwater sampling (Tables 4-12 and 4-13), surface water sampling (Table 4-14) and sediment sampling (Table 4-15) are enclosed at the end of Section 4.3.

## 4.1 POTENTIAL SOURCES

The potential sources of contamination and the potentially impacted media at the site are discussed briefly in this section. The potential sources were identified through analysis of the historical records and survey of the existing physical site features.

#### 4.1.1 Activities by Raytheon, Inc. at Building T104 (1958 to 1971)

While specific descriptions of the Raytheon, Inc. (Raytheon) activities at the site were not made available by Raytheon, it is apparent from the scattered site records and the remaining infrastructure at Building T104, that Raytheon conducted research and testing on electronic components for missile guidance and radar systems. This research was conducted in the "shielded area" of Building T104 indicated on facility maps, which has been identified in this report as the two "clean rooms" (Figure 4-1). Potential contaminants associated with this kind of research could include solvents used in cleaning electronic hardware and heavy metals associated with soldering and assembly of component parts. The likely amount of solvents used, however, is probably limited due to the need to avoid the buildup of moisture in electronic systems. To support the radio frequency shielding and the HVAC system, Building T104 was equipped with numerous pieces of electronic equipment including transformers. Inspection by Fort Devens in 1985 found that the large transformers that were part of the Building T104 infrastructure (as opposed to those transformers temporarily staged in Building T104) did not contain dielectric fluid, as was revealed by the attempts to strip copper wire from these units by scavengers.

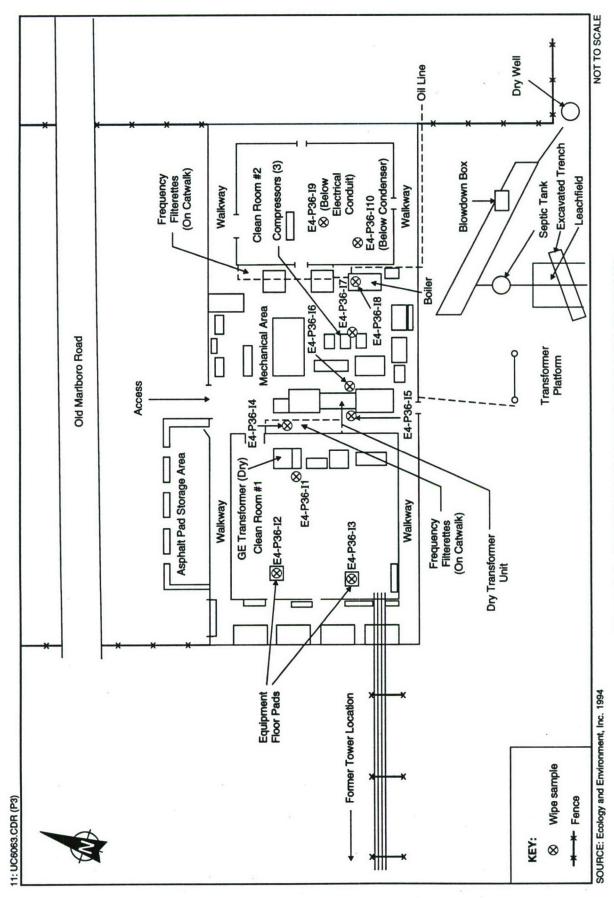


Figure 4-1 BUILDING T104 WIPE SAMPLING LOCATIONS

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# 4.1.2 Activities by Raytheon, Inc. at Building T106 (1958 to 1971)

The bulk of research by Raytheon at the Annex appears to have been conducted in Building T104, which had the infrastructure for conducting of testing and research on electronic components. Building T106 was apparently used for storage of materials and assembly of electronic components. Potential contaminants associated with this activity include solvents used for cleaning and heavy metals associated with assembly activity that may have impacted the floor of Building T106 or migrated into surrounding soils. The likely amount of solvents used in assembly of component systems, however, is probably limited due to the need to avoid the buildup of moisture in electronic systems.

# 4.1.3 Activities by the Air Drop Engineering Laboratory (Natick, 1971 to 1982)

The exact nature of research by the Air Drop Engineering Laboratory (ADEL) at the site has not been documented. ADEL is responsible for conducting impact testing on air delivery systems of personnel and equipment for the Army, and it is likely that ADEL's work at the site may have consisted of use of the detection tower for impact testing, and Building T106 for parachute assembly and preparation. No potential contaminants were identified for this activity.

# 4.1.4 Storage on Asphalt Pad Along North Side of Building T104

An asphalt pad with concrete footings is located along the north side of Building T104. This structure was at one time covered by a wooden roof. The pattern of the concrete footings suggest that this area was used to offload materials from trucks that backed up to the pad. While the exact nature of the materials used at Building T104 is unknown, potential contaminants include PCBs (if transformers were ever staged on the asphalt pad), solvents, or other material that may have been used inside the building by Raytheon or ADEL.

#### 4.1.5 Transformer Staging in Building T104 (1982 to 1985)

From sometime prior to August 1982 until 1985, Building T104 was used to stage transformers removed from other Annex buildings. As of early 1985, three transformers were staged in Building T104. While staged inside Building T104, one of the transformers was vandalized and had to be drained of its PCB-containing insulating fluid. A second transformer was tipped over while staged just outside Building T104. In addition, a third transformer containing PCBs was located on a platform south of Building T104. Potential contaminants are oil and PCBs that may have leaked on the floor of Building T104 and thus entered the floor drains or that may have leaked into soils outside the building.

## 4.1.6 PCB Spill (1985) and Remediation (1985 to 1986)

One of four transformers staged outside Building T104 in July 1985 was punctured by a bullet hole by vandals using the site for target practice. This transformer spilled between 100 to 200 gallons of PCB-containing oil that flowed approximately 90 to 100 feet downhill

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and to the northeast from Building T104. This spill resulted in contaminated asphalt and soil in the spill area. The spill was remediated in 1985 and 1986, with the removal of four transformers, PCB oil remaining in two of the transformers, and contaminated soil and debris in the area. Final sampling results in July 1986 indicated residual PCB levels in soil had been remediated to below 4 ppm. Potential contaminants are oil and PCBs from the original spill and soil contaminated with oil or PCBs that may have been missed by the remediation or been spilled during the remediation.

## 4.1.7 10,000 Gallon UST at Building T104 (1958 to 1988)

In December 1988, Environmental Applications, Inc. (EA), removed the 10,000 gallon UST located near the southeastern corner of Building T104. This UST had contained No. 2 Fuel Oil. No visibly contaminated soils or odors were noted. HNu readings of soil samples from the excavation did not indicate readings above background. No holes were observed in the tank and, according to the EA removal document, the pit was backfilled with material previously classified as acceptable. Petroleum hydrocarbon contamination is unlikely to exist related to this UST.

# 4.1.8 1,000 Gallon UST at Building T106 (1958 to 1988)

In December 1988, the 1,000 gallon UST used to store No. 2 Fuel Oil was removed from the northeastern corner of Building T106 by EA. Prior to the excavation, 75 gallons of waste oil were removed from the tank. The UST was reported to be in poor condition, with extensive corrosion and a 1-inch hole located in the side of the tank directly below the fill line. The soil surrounding the tank prior to removal was stained and emanated strong petroleum odors. Sixteen cubic yards of soil were removed from the tank pull area (EA 1989). Excavation of contaminated soil ceased at the foundation of Building T106 to avoid endangering its structural stability. Soil samples were taken from the bottom of the excavation and from the soil stockpile. Laboratory analytical results indicated concentrations of 6,521 ppm of TPHC in the excavation sample and 6,517 ppm of TPHC in the stockpile sample. The pit was backfilled with acceptable soil in December 1988. Potential contamination associated with the UST is petroleum hydrocarbons that have leaked into the soil and may have migrated into groundwater.

# 4.1.9 Existing Equipment in Building T104

In a building inspection by E & E personnel in April 1994, only two types of equipment in Building T104 were identified that might contain insulating fluid that could contain PCBs. This equipment includes three compressor units attached to the heating, ventilation, and air conditioning (HVAC) system, and two areas of frequency filterettes mounted on raised platforms adjacent to each of the two clean rooms. PCB-containing fluid, if contained in this equipment and if leaked, would fall on the Building T104 floor. There, it could possibly move when mixed with the rainwater that falls through holes in the roof of the building and so enter the floor drains that connect to the septic system.

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## 4.1.10 Summary of Sources

Potential sources of contamination at Building T104 include: several pieces of equipment that could contain PCBs; several transformers formerly staged at Building T104 that may have leaked on the floor or on the asphalt pad; one transformer on the platform south of Building T104 that may have leaked into surrounding soil; and limited amounts of solvents and heavy metals involved in electronic component research and testing by Raytheon that may have spilled on the Building T104 floor or the asphalt pad. Migration from inside Building T104 could be via the floor drains that lead to the septic tank and leach field, or through the seams of the floor and the holes between the concrete floor and the metal sheeting of the walls. Migration from the asphalt pad would be into surrounding soils on the north side of Building T104, and into the drainage path alongside Old Marlboro Road.

The source of contamination at the PCB Spill/Remediation area is the 1985 spill from a PCB-fluid containing transformer. It is also possible that, during removal activities, some of the PCB-contaminated soil may have been distributed in the immediate area beyond the initial spill.

Potential sources of contamination at Building T106 are the 1,000 gallon leaking UST removed in 1988, and limited amounts of solvent or heavy metals associated with the Raytheon electronic component assembly work conducted in the 1960s. Petroleum hydrocarbons from the UST have contaminated surrounding soils, as evidenced by the 1988 sampling during the removal, and could potentially migrate to groundwater. Any contamination from inside the building could have impacted on the floor of the building or surrounding soils outside the building. (No floor drains were noted in the building.)

Overall types of potential contamination include PCBs, petroleum hydrocarbons, solvents, and heavy metals. Solvents are not expected to be found today at the site because use of solvents was likely to have been very limited in the assembly for electronic components at the site. It is probable that solvents, if used would be used in small quantities to avoid moisture buildup in the electronic component systems, and thus residual amounts are more likely to have volatilized than migrated via surface runoff pathways.

#### 4.2 NATURE AND EXTENT OF CONTAMINATION

# 4.2.1 Wipe Sampling Inside Building T104

Analysis of the floor wipe samples indicate the presence of PCBs in nine out of ten of the samples in concentrations ranging from 0.040 to 2.00  $\mu$ g (micrograms)/100 cm² (wipe samples are collected using a 10 cm by 10 cm template). The two highest concentrations were found in the sample taken from the floor beneath the frequency filterettes attached to clean room No.1 (2.00  $\mu$ g/100 cm² at E4-P36-I04) and beneath one of the building compressors (0.200  $\mu$ g/100 cm² at E4-P36-I07). It is interesting to note that these two pieces of equipment were the only equipment identified in the building survey as those potentially containing fluid that may contain PCBs. The only sample location where PCBs were not

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detected was under the heating oil tank. The location of PCB building wipe samples are noted on Figure 4-1.

The detection of PCBs beneath the frequency filterettes and the building compressor points to these pieces of equipment as PCB sources. However, only actual sampling of the interior of these pieces of equipment would confirm these as actual sources. The source of the remaining PCB detections is uncertain, given that PCBs were detected at consistent levels (from 0.040 to  $0.140~\mu g/100~cm^2$ ) near or beneath a variety of equipment in the building. This pattern does not suggest any of the equipment, other than those identified above, as specific sources of PCBs, in particular since none of the remaining equipment apparently has any fluid that could contain PCBs. Thus, the remaining PCB detections are likely due to the dispersal of PCBs from other sources. These sources could include fugitive dust from the nearby excavations in the PCB spill/remediation area on the east side of Building T104, leakage from the frequency filterettes or the building compressors (if they actually contain PCBs), or leakage from equipment that has been removed from the building, such as the transformers (that did contain PCBs) that were staged at Building T104 in the early 1980s, and removed in 1985.

As a means of comparison, the wipe samples were compared to the United States Environmental Protection Agency (EPA) PCB Spill Cleanup Policy requirements for cleanup of indoor solid surfaces and high contact outdoor solid surfaces defined as high contact residential/commercial surfaces. The policy is listed in 40 CFR 761.120 and lists a cleanup level of  $10~\mu g/100 cm^2$ . None of the wipe samples taken in Building T104 exceeds this level. It is important to note that the wipe concentrations were compared to the levels appropriate to the highest contact scenario for potential future use. Thus while several potential sources may exist or have existed in the past in Building T104, current surficial levels on the building floors are unlikely to pose any risk. The greater concern regarding PCBs is that previous PCB spills or leakage may have resulted in migration of PCBs in the septic system via the Building T104 floor drains, or migrated into soils surrounding the buildings.

# 4.2.2 Building T104 Septic Tank and Leach Field

The floor drains in Building T104 connect to a septic tank located approximately 20 feet south of the building. This septic tank, in turn, drains into a leach field south of the tank. A sludge sample at location E4-P36-P02 was collected from the septic tank to characterize any potential contamination that may have drained from the building via the floor drains. At the time of sampling, the septic tank appeared nearly full to the top with sludge, and a petroleum-like sheen was observed on the material in the tank. As the sample was collected from the top of the sludge, the material became more and more aqueous, indicating that the material may have actually had a high percentage of liquids. Analysis of the sample indicated the presence of numerous metals. Although no true background exists for septic tank sludge, the following compounds were found to exceed background soil levels: antimony, barium, cadmium, calcium, chromium, copper, manganese, nickel, selenium, silver, and zinc. All of these, except manganese, were found at concentrations more than twice background levels in soils and suggest that the sludge accumulated metals from the floor drains.

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The only volatile organic compounds positively identified in the septic sludge sample were carbon disulfide at 0.100  $\mu$ g/g, o-xylene at 0.100  $\mu$ g/g, m- or  $\rho$ -xylene (undifferentiated), at 0.200  $\mu$ g/g, and cis 1,2-dichloroethylene at 3.00  $\mu$ g/g. Carbon disulfide and cis 1,2-dichloroethylene can both be used as solvents. The detection of the xylenes is probably related to the high amount of total petroleum hydrocarbons founds in the sample, but could also be related to solvent use. Acetone and methylene chloride were detected in the sample but were also found in laboratory blanks. Carbon disulfide also is a potential laboratory artifact from the sulfur-rich matrix. Several semivolatile organic compounds were also detected, including 2-methylphenol at 80.0 µg/g, and several PAHs. PAHs detected were acenapthene, anthracene, naphthalene, and phenanthrene, and are probably related to the petroleum hydrocarbons detected in the sludge.

PCBs, in the form of PCB 1254, were found in the septic tank sludge at 6.90  $\mu$ g/g. TPHC was also detected at 200,000  $\mu$ g/g in the sludge, indicating that the sludge sample consisted of 20 percent TPHC.

The septic tank drains into the leach field, which starts approximately 45 feet south of Building T104 and extends in a southeasterly direction. A test pit (E4-P36-P01) was excavated across the leach field at a point approximately 60 feet south of Building T104. The pit was excavated to a depth of 4 feet BGS, across a length of approximately 20 feet, with a width of approximately 2 feet. Subsurface soil samples were collected from the soil beneath each of the three leach field pipes to identify if any contaminants may have migrated via the septic system in Building T104. Metals found at concentrations above background surface soil levels included: antimony, barium, chromium, potassium, and zinc. Of these, only antimony (at 2.02  $\mu$ g/g), potassium up to 1,410  $\mu$ g/g, and zinc (up to 150  $\mu$ g/g) were found in concentrations more than twice background levels. Potassium was not found in the septic tank, and the detections in the leach field are probably not site-related.

No volatile organics were found in the leach field samples, except methylene chloride which was also found in laboratory blanks. The only semivolatile organic compound found was butyl benzyl phthalate at 0.130  $\mu$ g/g. Butyl benzyl phthalate is a common plasticizer and is probably a field sampling artifact.

PCBs, in the form of PCB 1260, were detected in two of the three leach field soil samples, at concentrations up to 0.190  $\mu$ g/g. Given the 4-foot depth of the leach field soil samples, and that PCBs were found in the wipe samples in Building T104, and in the septic tank, some low concentrations of PCBs have apparently migrated from Building T104 via the floor drains, into the septic tank, and into the leach field. TPHC was also detected in two of three leach field soil samples. However, the levels of TPHC in the leach field (maximum 15.6  $\mu$ g/g) were significantly lower than the TPHC found in the septic tank sludge (200,000  $\mu g/g)$ .

#### 4.2.3 Surface Soil

Analysis of 18 soil samples collected around the perimeter of Buildings T104 and T106 indicated the presence of the following inorganic analytes above background soil levels

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in more than half of the samples: barium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, and zinc. Almost all of the inorganic analytes, with the exception of mercury and silver were found in at least one sample above background level. The following inorganic analytes were found in at least one soil sample at a level more than twice the background level: antimony, barium, cadmium, calcium, chromium, cobalt, copper, iron, manganese, nickel, potassium, sodium, thallium, and zinc. The following analytes were only found in one of eighteen samples above background levels: arsenic, lead, thallium, and vanadium.

Concentrations of inorganic analytes were generally elevated in those soil samples collected from around Building T104 as compared to those collected from around Building T106. The highest concentration in soil samples for antimony, arsenic, barium, cobalt, copper, lead, manganese, nickel, and sodium were all found in the soil sample at E3-P36-S01, which was collected from soil on the north side of Building T104. The highest concentrations of aluminum, cadmium, calcium, magnesium, and potassium, and zinc were all found in the soil sample at E3-P36-S09, which was taken underneath the raised metal stands for the electrical connections that formerly ran west from Building T104 to the detection tower. The highest concentrations of chromium was found in the soil sample at E3-P36-S10, collected from soil along the west side of Building T104. The pattern of detections could indicate some low level metals contamination related either to rusting and decay of the building itself, historical activity in Building T104, or to the metal debris scattered around the perimeter of the building.

The pattern of metal detections in surface soils at Building T106 does not suggest any site-related metal contamination in soil. Inorganic analytes found in Building T106 samples included chromium (but only in one of six samples), manganese, nickel, and zinc. Of these, only zinc was found at levels more than twice background soil levels, and this may be derived from galvanized steel in the building structure.

No volatile organic compounds were detected in any surface soil samples collected at the site. Semivolatile organic compounds detected in surface soil samples at the site include: bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, and several PAH compounds (benzo(b) fluoranthene (at  $0.082~\mu g/g$ ), fluoranthene (at  $0.081~\mu g/g$ ), and pyrene (at  $0.090~\mu g/g$ ). The PAH compounds were only detected in one of eighteen soil samples, at the sample collected at E3-P37-S07. Bis(2-ethylhexyl)phthalate was found in four out of six samples from around Building T106, up to  $1.30~\mu g/g$ . Butyl benzyl phthalate was found in only one sample, at E3-P36-S01, on the north side of Building T104, at a concentration of  $0.600~\mu g/g$ . As noted above the phthalates are common plasticizers, and these detections are likely to be field sampling artifacts.

Several pesticides were detected in soil samples at the site.  $\beta$ -Endosulfan was found in six of eighteen samples collected around Building T104 above the background level of 0.004  $\mu$ g/g, and in one sample around Building T106, but a level below the background level. The highest detection of  $\beta$ -endosulfan was 0.111  $\mu$ g/g at E3-P36-S12. DDT was found in most of the soil samples collected at the site, but was only found above the background level of 0.230  $\mu$ g/g in three samples collected from around Building T104. The highest detection

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of DDT was at E3-P36-S07, on the south side of Building T104, at 0.940  $\mu$ g/g.  $\gamma$ -Chlordane was found in two soil samples from around Building T104, but was above the background level of 0.005  $\mu$ g/g in only one sample at E3-P36-S01. The only other pesticide found above background levels was methoxychlor in one sample at 0.018  $\mu$ g/g from the PCB spill/remediation area (see Table 4-7).

For the investigation of the PCB spill/remediation area, samples from 20 surface soil samples (E3-A12-S01 through S20), collected in the vicinity of spill/remediation area (see the Plate at the end of this volume) were screened using the ENSYS PCB RISc Test System. The screening results indicated the potential presence of PCBs above 10 ppm in five surface soil samples (E3-A12-S02 through S06). Two of these five samples, E3-A12-S02 and E3-A12-S03 were sent to the laboratory for confirmatory analysis, which found low levels of PCB-1260 in both samples (up to  $0.261 \mu g/g$ ). The actual instrument readings for these five samples were not recorded during field screening, however, the fact that PCBs were present, giving a negative reading, was recorded (see Table 4-2).

PCBs were also found in 14 of 18 surface soil samples collected from around Building T104, but were not found in any of the surface soil samples from around Building T106. PCB 1260 was detected in seven of the eight soil samples taken on the north side of Building T104 up to a level of 6.30  $\mu$ g/g (at E3-P36-S13). The two highest concentrations of PCBs (4.70  $\mu$ g/g and 6.30  $\mu$ g/g) found in surface soil from the site were both from soil in the asphalt pad area along the north side of Building T104. PCB 1260 was detected in all three samples on the east side of Building T104 up to 1.20  $\mu$ g/g, although these levels may have been influenced by the adjacent PCB spill and remediation area. PCBs were detected (as either PCB 1254 or PCB 1260) in three of five samples taken south of the building up to 3.50  $\mu g/g$ , with the highest detection at E3-P36-S07. PCBs were not detected in the two samples taken beneath the wooden platform that formerly housed a transformer connected to Building T104. PCB 1260 was detected in one of two samples taken on the west side of the building at a level of 0.750 µg/g. While some of the PCB detections may result from spillage of soil excavated during the remediation of the PCB spill east of Building T104, the consistent detection of PCBs around Building T104 points to a source either within or immediately outside the building. In particular, the higher detections at the asphalt pad indicates a potential spill of material containing PCBs, perhaps from one of the transformers staged at the site, or other material stored in the former covered storage area alongside the north edge of Building T104.

TPHC was detected in all but one of the soil samples in a range from 18.3  $\mu$ g/g to 1,800  $\mu$ g/g. Nine of 18 soil samples at Building T104 had TPHC concentrations above 100  $\mu$ g/g. TPHC concentrations in the soil samples from around Building T106 were all below 100  $\mu$ g/g. Only two of the soil samples at Building T104, at E3-P36-S01 (920  $\mu$ g/g) and at E3-P36-S12 (1,800  $\mu$ g/g) had TPHC concentrations above 500  $\mu$ g/g. It is important to note that none of the volatile components of petroleum such as benzene, toluene, ethylbenzene, or xylene were detected in any soil samples at the site.

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#### 4.2.4 Subsurface Soils

Subsurface soil borings were conducted around Building T104, Building T106 and the PCB spill/remediation area. For the investigation of the PCB spill/remediation area, samples from four borings (E3-A12-B01/B02/B03/B04) were screened using the ENSYS PCB RISc Test System at two depths. All of the boring samples were then sent to the laboratory for confirmatory analysis. The field screening data are presented in Table 4-2. Field screening results indicated that only one boring, E3-A12-B04, at the first sampling depth showed any qualitative level of contamination above 10 ppm. The boring locations are indicated on the Plate at the end of this volume. Soil samples from the four soil borings were laboratory analyzed for pesticides and PCBs. No pesticides or PCBs were detected in any of the samples.

Analysis of soil samples taken from the three borings south, west, and north of Building T104 indicated the presence of metals, one phthalate, and TPHC. The metals found above background surface soil levels included: aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, thallium, and zinc. However, the highest concentrations found for these metals was in most cases only slightly above background surface soil levels. Only cadmium, potassium, and thallium were found in concentrations more than twice background soil levels. Cadmium was found at a depth of 4 feet in both the E3-P36-B01 (7.77  $\mu$ g/g) and E3-P36-B02 (64.3  $\mu$ g/g) borings at well above background level ( $< 0.500 \mu g/g$ ). Cadmium was also found in these borings at a depth of 14 feet, but at much lower levels (below the reporting limit of 0.500 μg/g). Potassium was consistently elevated in all borings samples taken at Buildings T104 and T106, and probably reflects natural conditions. Thallium, which was not detected in background samples, was detected at low levels (up to 0.233  $\mu$ g/g) in four out of six boring samples from the borings around Building T104. Di-n-octyl phthalate was detected in the sample from a depth of 4 feet at E3-P36-B01 at 0.120  $\mu$ g/g, but is probably a field sampling artifact. TPHC was detected at low levels in the samples from the E3-P36-B03 sample only, up to a level of 15.2  $\mu$ g/g

Three subsurface soil borings were conducted in the area immediately south of Building T106, and metals, several semivolatile organic compounds, and TPHC were detected. In analysis of samples from the borings, the following metals were detected in concentrations above surface soil background levels: barium, calcium, chromium, cobalt, magnesium, manganese, nickel, and potassium. Of these, only potassium was found in a concentration more than twice the background level. Barium, chromium, and magnesium were only found in one of the six boring samples at Building T106, in the sample taken at a depth of 14 feet from E3-P37-B03. One semivolatile organic compounds, di-n-octyl phthalate, a common plasticizer, was also detected. Di-n-octyl phthalate was detected at the 14-foot depth of E3-P37-B03, but its probably a field sampling artifact. Low levels of TPHC (27.6  $\mu$ g/g, maximum) were detected in five out of six boring samples at Building T106.

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#### 4.2.5 Groundwater

The E3-P36-M01 well was installed near the crest of the hill to the northwest of Building T104 in a location upgradient of any potential contaminant sources, and analysis of groundwater samples from this well were used to characterize background levels for metals in groundwater at the site. The full analysis results for E3-P36-M01 are included in Table 4-12 below.

Analysis of the unfiltered groundwater samples from the six downgradient wells (E3-P36-M02 and M03, E3-P37-M01/M02/M03) indicated the following inorganic compounds in concentrations above those in the background well: antimony, arsenic, lead, manganese, and zinc. Analysis of filtered groundwater samples from the downgradient wells indicated the following inorganic compounds above the background well levels: arsenic, barium, calcium, chromium, cobalt, magnesium, manganese, potassium, vanadium, and zinc. The frequency of detection of these compounds, highest detections, and frequency above background of inorganic analytes in filtered groundwater are noted in Table 4-1 below.

Most of the metals found in filtered samples were only detected in concentrations above background in one or two samples, with the exception of barium which was found in three out of ten sample above the background level. Metals are naturally present in groundwater, and naturally existing levels can fluctuate. Given there was only one background well and that arsenic, barium, calcium, magnesium, manganese, and potassium were found in filtered samples at concentrations less than twice the background level, the concentrations of these metals are probably natural levels. Cobalt, chromium, and vanadium were not found in the filtered sample from the background well but were only found in one of ten samples from the downgradient well. Only one compound, zinc at 71.9  $\mu$ g/L in one of two samples collected from the E3-P37-M03 well, was found at a concentration more than twice the background level. Given that cobalt, chromium, vanadium, and zinc were not detected in any one downgradient well in both rounds of sampling, the concentrations of these metals are probably naturally occurring as well.

The only organic compounds detected in downgradient wells at the site were bis(2ethylhexyl)phthalate and TPHC. Bis(2-ethylhexyl)phthalate was detected in the September 1993 sampling round in well E3-P36-M03 at 4.40 µg/L and in well E3-P37-M03 at 2.50 μg/L, but was not detected in the December 1993 sampling round in any well. Given that bis(2-ethylhexyl)phthalate is a common plasticizer found in field sampling gloves and other field sampling equipment and that it was not found in both sampling rounds, the detection in one round in two wells is probably a field sampling artifact.

TPHC was found in concentrations above those in background well in the December 1993 sampling round in well E3-P37-M01 at 1,290  $\mu$ g/L and in well E3-P37-M02 at 1,930 μg/L. TPHC was not detected in other wells at the site, and was not detected in any wells in the September 1993 sampling round. Well E3-P37-M01 was installed in the parking lot area, and the TPHC detection is probably related to runoff from vehicles formerly parked in this area. Well E3-P37-M02 was installed just south of Old Marlboro Road and the TPHC detection may reflect petroleum leakage along the road, but may also be related to the leaking

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			Table 4-1		
DE	TECTIONS IN	GROUNDW	ATER ABOVE	BACKGROUND	(μg/L)
Compound	Frequency Detected ¹	Max Concen- tration	Site ID	Max. in Local Background ²	Frequency Above Background
Arsenic	4/10	2.14	E3-P37-M01	1.31	2/10
Barium	8/10	10.2	E3-P37-M02	7.75	3/10
Calcium	10/10	6980	E3-P37-M02	6400	1/10
Chromium	1/10	4.0 J	E3-P36-M02	ND	1/10
Cobalt	1/10	2.20 J	E3-P36-M03	ND	1/10
Magnesium	10/10	1220	E3-P37-M01	909	2/10
Manganese	8/10	224	E3-P36-M03	124	2/10
Potassium	7/10	1250	E3-P36-M02	1170	1/10
Vanadium	1/10	4.73 J	E3-P37-M02	ND .	1/10
Zinc	1/10	71.9	E3-P37-M03	22.4	1/10
Bis (2- ethylhexyl) phthalate	2/10	4.40 J	E3-P36-M03		2/10
TPHC	2/10	1930	E3-P37-M02	217	2/10

⁵ downgradient wells were sampled in each of two rounds

Note: Metals are from filtered samples only, and were compared to filtered samples of local background well

Source: Ecology and Environment, Inc. 1994

UST formerly connected to Building T106. No volatile constituents of petroleum such as benzene, toluene, ethylbenzene, or xylene (BTEX) were detected in any wells at the site.

#### 4.2.6 Surface Water

Three surface water and sediment samples were collected in Marlboro Brook to characterize any potential impact from the site on the brook, which drains to Hop Brook. It is important to note that all three of these samples are downstream of other sites in Watershed 2, including Site P28 (the Rocket Range/Railroad Classification Yard), and Site A11 (the leach field). While all of the surface water/sediment sample points are downgradient of Building T104, the PCB spill/remediation area, and Building T106, for ease of reference, these sample points will be referred to by their relative position in Marlboro Brook. The first sample (at E3-P37-D01) will be referred to as the upper sample, the second sample (at E3-P37-D02) as the middle sample, and the third sample (E3-P37-D03) as the lower sample. Surface water/sediment sample locations are noted on the Plate at the end of Volume I.

In analysis of the three surface water samples, the following metals were detected above surface water background levels: aluminum, arsenic, barium, chromium, cobalt, iron,

² Local background well is E3-P36-M01

J = estimated value

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lead, manganese, nickel, vanadium, and zinc. It is important to note that background surface water levels were established based on only two background surface water samples collected at stream points upgradient of any known sites at the Annex. Thus, background levels are poorly characterized and may underestimate or overestimate true background levels in surface water at the Annex. The metal detections above background in surface water were only at the upper and lower surface water samples. No metals were found in concentrations above background in the middle sample (at E3-P37-D02), except zinc. The only other compound detected in the surface water samples was bis(2-ethylhexyl)phthalate, which was found in the upper and middle samples but not at the lower sample. The highest detection of this compound (at 24.0 µg/L) was in the middle sample at E3-P37-D02, where no metals except zinc were found above background. Given that this phthalate is a common plasticizer, its detection is probably a field sampling artifact.

It is important to note that several metals were significantly elevated in surface water sampled collected in Marlboro Brook upstream of the entrance of any drainage from the RI site. Of those compounds found above background in the three surface water samples downgradient at the site, arsenic (up to 440  $\mu$ g/L), chromium (at 20  $\mu$ g/L), iron (up to 130,000  $\mu$ g/L), lead (up to 107  $\mu$ g/L), and zinc (up to 146  $\mu$ g/L) were found at higher levels in upstream samples. The detections of arsenic, iron, and lead in surface water probably are not related to the RI site for the following reasons: these detections are further upstream; the arsenic, iron, and lead were not found in filtered groundwater samples above background levels at the RI site; and these metals were only infrequently found at levels slightly above background in surface and subsurface soil samples collected at the site. However, these detections may indicate contamination of Marlboro Brook from other sites at the Annex, such as P28, P38, or A11.

## 4.2.7 Sediment

Analysis of the three sediment samples indicated elevated concentrations of most metals above their respective local sediment background levels. It is important to note, however, that only two local background sediment samples were collected at the Annex, and thus the background sediment levels for inorganic analytes are poorly established and may underestimate or overestimate the true range of sediment background levels for the Annex. The two background sediment samples were collected in streams that had sediments with relatively low TOC content (maximum of 14,200  $\mu$ g/g, 1.4 percent), especially in comparison to samples collected in wetland areas at the Annex that can have TOC content up to 50 percent. Two of the sediment samples for investigation of this site (E3-P37-D01 and E3-P37-D03) had TOC content greater than 25 percent. One of the sediment samples (E3-P37-D02) had a TOC of 10,800  $\mu$ g/g which was similar to the local sediment background samples. Organic-rich sediments will tend to have consistently higher natural metals concentrations due to the greater sorbing potential of sediments with large amounts of organic carbon. Thus, the two background sediment samples are most likely to underestimate background levels of metals in sediment, particularly for organic-rich sediments. Inorganics found in sediments were compared to the background stream levels, but were also compared to the metals concentrations found in the background pond (Ministers Pond), when the TOC content was

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greater than 10 percent. The background pond sediments had TOC contents ranging from 34 to 58 percent.

In the upper sediment sample (at E3-P37-D01), with a TOC content of 254,000  $\mu$ g/g, the following metals were found in concentrations above the stream sediment background levels: arsenic, beryllium, calcium, copper, lead, manganese, nickel, selenium, and zinc. However, in comparison to the organic-rich sediments of the background pond, only beryllium (0.734  $\mu$ g/g), manganese (203  $\mu$ g/g), and selenium (0.852  $\mu$ g/g) were found above the background pond range.

In the middle sample (E3-P37-D02), with a TOC content of 10,800, the following metals were found above the Annex sediment background levels: arsenic, beryllium, chromium, cobalt, magnesium, manganese, nickel, and zinc. However, the detections of arsenic, beryllium, chromium, cobalt, manganese, nickel, and zinc were all found in concentrations only slightly above the local background sediment levels for these metals. Given that all of these detections are less than twice the background levels for sediment, and the limited number of background sediment samples collected, it is likely that these detections reflect naturally occurring levels of these metals in the sediment. The only metal detection in the middle sample that significantly exceeds sediment background levels is magnesium (at  $203,000 \mu g/g$ ), which is nearly 100 times the background level.

In the lower sample (E3-P37-D03), with a TOC content of 372,000  $\mu$ g/g, almost all of the metals detected, with the exception of aluminum, magnesium, potassium, selenium, and thallium, were found above the background stream sediment levels. Most of the metals, including arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, iron, manganese, and zinc were also found above the range for metals found in sediment from the background pond.

Arsenic was elevated above the Annex sediment background level in all three sediment samples, and was above the background pond level in one of the sample. The concentrations in the upper and middle samples (8.72  $\mu$ g/g and 3.01  $\mu$ g/g, respectively) were significantly lower than in the lower sample (37.4  $\mu$ g/L). This pattern may reflect the differences in TOC content of the sediments, which was highest (372,000  $\mu$ g/g) in the lower sample.

The pattern of detections for other metals, were in general, similar to arsenic, with the lowest values found in the middle sample, higher levels in the upper sample, and highest levels in the lower sample where organic carbon content was the highest. As noted above, several metals were significantly elevated in surface water samples collected in Marlboro Brook upstream of the entrance of any drainage from the RI site. The detections of metals in sediment samples are unlikely to be related to the RI site because these detections were further upstream, the metals were not found in filtered groundwater samples above background levels at the RI site, and the metals were only infrequently found at levels slightly above background in surface and subsurface soil samples collected at the site. However, these detections may indicate contamination of Marlboro Brook from other sites at the Annex, such as P28, P38, or A11.

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The only volatile compound detected in sediments downgradient of the site was toluene (0.030  $\mu$ g/g) which was found at a trace level in the upper sample.

Two polynuclear aromatic hydrocarbons (PAHs), fluoranthene (at  $0.290 \mu g/g$ ) and pyrene (at  $0.310 \mu g/g$ ), were detected in the lower sediment sample only, possibly due to passing automobile traffic along Moore Road. PAHs were found in only one of eighteen soil samples at the site itself, and were not detected in surface water or groundwater sampling points downgradient of the site. The detections in the soil sample at the site were less than  $0.100 \mu g/g$ , which is lower than the two detections at the lower sediment sample. Thus, the source of the PAHs is probably local to the sample.

TPHC was only found (at 174  $\mu$ g/g) in the lower sample. TPHC was detected in most of the soil samples at the site and in several groundwater samples, indicating a potential connection with the sediment detections. Given the proximity of the sediment sample to Moore Road, the distance of the sample point from the site itself, and the non-detection of TPHC or PAHs in the other two sediment samples, it is likely that TPHC detection in the lower sample is not site-related. TPHC was not found above the level in local background sediment samples anywhere in Marlboro Brook except at the lower sample, which is actually located off the Annex property along Moore Road.

Several pesticides were detected in sediment samples. At the upper sample, endrin (at 0.024  $\mu$ g/g) and DDE (at 0.097  $\mu$ g/g) were found. At the middle sample,  $\beta$ -endosulfan (at  $0.001 \mu g/g$ ) was the only pesticide found. The highest concentrations of pesticides were found in the lower sample including:  $\gamma$ -chlordane (0.190  $\mu$ g/g),  $\alpha$ -BHC (0.027  $\mu$ g/g), heptachlor epoxide (0.114  $\mu$ g/g), and DDE (0.345  $\mu$ g/g). DDE was also detected further upstream near Site A11 in surface water and sediment. While  $\gamma$ -chlordane and  $\alpha$ -BHC were also found in other Marlboro Brook samples near site A11, the concentration at the lower sediment sample along Moore Road were the highest detections of this pesticide in E & E sampling in Marlboro Brook. Heptachlor epoxide was only found in Marlboro Brook at the lower sample. This pattern of detections is inconclusive as to the source of these pesticides. Pesticides were not found in groundwater, surface water, or subsurface soil samples collected from locations downgradient of Buildings T104 and T106, and the PCB spill/remediation area.  $\beta$ -Endosulfan,  $\gamma$ -chlordane, DDT and methoxychlor were found above background soil levels in some of the soil samples from near Building T104, but DDT and/or its degradation products were also found in surface waters and sediments near Site A11 further upstream in Marlboro Brook. Further, there is no consistent pattern of detections of pesticides in sample downgradient from the site. Thus, these detections could be the result of runoff from the Annex (including from the site area) due to past pest management practices, but in the case of the lower sediment sample at Moore Road, could also be influenced by off-site pest management practices both past and present.

# 4.3 CONCLUSIONS

Floor wipe samples in Building T104 indicate the presence of PCBs in the building. While the levels found in wipe samples are well below EPA PCB spill cleanup levels for high contact residential or commercial surfaces, their presence indicates potential sources presently

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or formerly located in the building. The only likely present potential sources are the building compressors, and the two rows of frequency filterettes located on overhead racks outside each of the two clean rooms. Former PCB sources that could have resulted in the PCBs found in the wipes are the three transformers staged in the building prior to 1985, and fugitive dust containing PCBs that may have migrated during the excavations in the PCB spill/remediation area just east of Building T104.

Sampling of the septic tank indicated the presence of metals, low levels of several volatile organics including carbon disulfide, several forms of xylene, and cis 1,2-dichloroethylene, PCBs, and TPHC. Some of the metals found in the sludge, such as cadmium, chromium, nickel, or silver could be related to the former electronic component research work conducted in the building. The volatile organics could indicate former use of solvents inside the building. The PCB concentrations (6.90  $\mu$ g/g) and high TPHC level (200,000  $\mu$ g/g) indicate that petroleum products, perhaps containing PCBs migrated via the Building T104 floor drains into the septic tank. Several PAH compounds were also found in the sludge sample, and are probably related to the high TPHC detection.

Sampling of the leach field indicated that most of the contaminants found in the septic tank, with the exception of PCBs and some low level TPHC, have not migrated into the soil via the leach pipes. While several metals were found above background soil levels, only antimony and potassium were found in concentrations more than twice soil background levels. No volatile organics were found in the leach field soil samples, and the only semivolatile compound found was a common plasticizer. PCBs (0.190  $\mu$ g/g, maximum) and TPHC (15.6  $\mu$ g/g, maximum) were found in the leach field samples but at much lower levels than in the septic tank sludge.

In surface soil samples, the sampling data indicate some limited metals, PCB, pesticides, and TPHC potential contamination around Building T104, low levels of PCBs in the former PCB spill/remediation area, and low level PAH and TPHC contamination around Building T106. PCBs were the greatest concern identified by surface soil sampling. PCBs were found in almost all of the samples collected around Building T104 (up to  $6.30~\mu g/g$ ), with the highest detections found in the asphalt pad area on the north side of the building, that was formerly used as a storage shed. The pattern of detections points to a potential low-level spill in the asphalt pad area, migration of PCBs out of the building through water runoff, or migration of PCBs from either the transformer staging done in and around Building T104, or from contaminated soil during the PCB spill remediation in 1985 and 1986. PCBs in soils in the actual PCB spill/remediation area east of Building T104 were quite low (0.261  $\mu g/g$ , maximum) indicating that the remediation effort in the actual spill/remediation area was effective. No PCBs were found in soils around Building T106.

The metals found at levels above background around Building T104 may be related to the metal debris found around the perimeter of the building, although some could potentially be related to the former research activity conducted in the building. The highest metals detections were found in three samples, collected from under the metal stands that used to support he electrical connections from Building T104 to the former detection tower (E3-P36-09), one from the area on the north side of the building (E3-P36-S01), and one near some

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metal debris on the west side of the building (E3-P36-S10). The metals around Building T104 were not particularly elevated. Several pesticides including  $\beta$ -endosulfan, DDT, and  $\gamma$ -chlordane, were found above background in a few samples from around Building T104. Methoxychlor was also found at a trace level in soil at the PCB spill/remediation area. These detections probably indicate the use of pesticides in the site area for pest management practices, but the concentrations do not indicate a spill of pesticides affecting soils. No volatile organics were found in surface soil. Semivolatiles detected included several phthalates, which are likely field sampling artifacts, and trace levels of several PAH compounds in one sample taken near Building T106. TPHC was found in all but one of the soil samples, and the pattern of concentrations indicate that the north side of Building T104, where two samples had TPHC concentrations above 500  $\mu$ g/g may have experienced some spills of petroleum products sometime in the past. Soil samples from other parts of the site contained relatively lower levels of TPHC (lower than 500  $\mu$ g/g), which were probably related to vehicle traffic, runoff from the former parking area or the nearby road, or some low level spills of petroleum products.

Subsurface soil sampling indicated elevated levels of several metals in borings around Building T104, and low levels of TPHC in borings from both Buildings T104 and T106. No PCBs or pesticides were found in any subsurface soil borings, including those collected in the PCB spill/remediation area. No volatile organic compounds were found, and the semi-volatile compounds detected were only low levels of several phthalates which are common plasticizers and likely to be field sampling artifacts. Metals were detected in the borings at Building T104 above background levels, but only cadmium, potassium, and thallium were found in concentrations more than twice background levels. The cadmium detection in particular was found at a significantly elevated level (64.2  $\mu$ g/g), considering that cadmium was not detected in any of the background soil samples. Potassium was consistently elevated in all boring samples, and probably reflects natural conditions. Thallium was not found in background soil samples, but was only found in low concentrations in the Building T104 borings (0.233  $\mu$ g/g, maximum). While metals were found above background in the Building T106 borings, only potassium was found in a concentration more than twice the background level.

Groundwater sampling did not indicate the presence of any metals in filtered samples that are likely to be site-related contaminants. When compared to filtered samples from the background well, metals detected in filtered samples from the five downgradient wells, only exceeded the background level in one of two samples, with the exception of barium, which was found in three out of ten total samples. The only metal found in downgradient wells at a level more than twice the background level was zinc, in one of two samples from the E3-P37-M03. Given this pattern of detections, groundwater is not considered to be contaminated with metals from the site. The only organic compounds found in downgradient wells were a phthalate and TPHC. The phthalate is a common plasticizer, and as such, could be a common field sampling artifact. TPHC was found at levels elevated above background in one of two rounds of sampling in the monitoring well in the former parking lot (E3-P36-M01), and the monitoring well on the northwest side of Building T106 (E3-P37-M02). While a leaking UST contaminated soils on the northeast side of Building T106, groundwater flow from the former UST location is to the east and away from the wells where TPHC was found. TPHC was not found in the well installed just northeast of the former UST location at

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Building T106. The TPHC detections are more likely to be related to infiltration of petroleum from the parking area and the nearby road, or spills in the these areas.

Surface water sampling indicated levels of metals were elevated in two of three samples collected. However, given the limited number of background surface water samples, the background levels may under represent the actual background range for streams at the Annex. Metals found above background levels included: aluminum, arsenic, chromium, cobalt, iron, lead, manganese, nickel, vanadium, and zinc. Some of these metals are probably due to sources located further upstream as indicated by detection of arsenic, chromium, iron, lead, and zinc in samples collected near A11. As indicated above, groundwater at the site is not considered to be contaminated with metals, and thus is unlikely to be a source of the elevated metals in surface water in Marlboro Brook. As noted, metals were elevated in some of the soil samples collected from near Building T104, but soil samples from around Building T106, which are the furthest downgradient on the entire site, did not have particularly high concentrations of metals.

Sediment sampling also indicated elevated concentrations of some metals. However, most metals found in two of the sediment samples were either below or just slightly above background levels when samples are compared to background levels with similar TOC content. Metals were elevated in the sediment sample collected in the wetland along Moore Road. Of particular concern is the detection of arsenic, which has been raised as a concern at numerous sites across the Annex. Arsenic and other metals were found further upstream in Marlboro Brook above the RI site and was also found consistently in soils at Site P28 and Site P38 above the headwaters of Marlboro Brook. Given that metals contamination was not identified in groundwater sampling at the site, and that metals contamination in soils at the site were limited, the likely source of metals in Marlboro Brook is not the site, but sources further upstream. Pesticides were also found in sediment samples, with the highest concentrations found in the lower sample taken in the wetland along Moore Road. The pattern of detections suggests the source of these pesticides is runoff containing residual pesticides from past pest management practices at the Annex. However, the detections at the lower sample along Moore Road could also be influenced by off-site pest management practices. Several PAH compounds and TPHC were found only in the sediment sample near Moore Road. TPHC was found in soils and groundwater at the site, but not in the surface water or sediment samples taken along Marlboro Brook at points closer to Building T104, Building T106, and the PCB spill/remediation area. This pattern points to off-site traffic or runoff associated with Moore Road as a potential source.

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Table 4-2 FIELD TEST RESULTS FOR PCB SCREENING OF SURFACE SOIL SAMPLES

Site ID	Standard	Reading	Standard Reading	Conclusion
E3-A12-S01	1 ppm	NR	NR	<1.0
E3-A12-S01	10 ppm	NR	NR	<10.0
E3-A12-S02	1 ppm	NR	NR	>1.0
E3-A12-S02	10 ppm	NR	NR	>10.0
E3-A12-S03	1 ppm	NR	NR	>1.0
E3-A12-S03	10 ppm	NR	NR	>10.0
E3-A12-S04	1 ppm	NR	NR	>1.0
E3-A12-S04	10 ppm	NR	NR	>10.0
E3-A12-S05	1 ppm	NR	NR	>1.0
E3-A12-S05	10 ppm	NR	NR	>10.0
E3-A12-S06	1 ppm	NR	NR	>1.0
E3-A12-S06	10 ppm	NR	NR	>10.0
E3-A12-S07	1 ppm	+2.47	-0.04	<1.0
E3-A12-S07	10 ppm	+2.48	-0.04	<10.0
E3-A12-S08	1 ppm	+2.47	-0.04	<1.0
E3-A12-S08	10 ppm	+2.48	-0.04	<10.0
E3-A12-S09	1 ppm	+0.03	-0.04	<1.0
E3-A12-S09	10 ppm	+0.01	-0.04	<10.0
E3-A12-S10	1 ppm	+0.50	-0.04	<1.0
E3-A12-S10	10 ppm	+2.20	-0.04	<10.0
E3-A12-S11	1 ppm	+1.65	-0.04	<1.0
E3-A12-S11	10 ppm	+2.48	-0.04	<10.0

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Table 4-2
FIELD TEST RESULTS FOR PCB SCREENING OF SURFACE SOIL SAMPLES

Site ID	Standard	Reading	Standard Reading	Conclusion
E3-A12-S01	1 ppm	· NR	NR	<1.0
E3-A12-S01	10 ppm	NR	NR	<10.0
E3-A12-S12	1 ppm	+2.47	-0.04	<1.0
E3-A12-S12	10 ppm	+2.48	-0.04	<10.0
E3-A12-S13	1 ppm	+2.47	-0.06	<1.0
E3-A12-S13	10 ppm	+2.47	-0.06	<10.0
E3-A12-S14	1 ppm	+2.48 +2.47	-0.06	<1.0
E3-A12-S14	10 ppm		-0.06	<10.0
E3-A12-S15	1 ppm	+2.47	-0.06	<1.0
E3-A12-S15	10 ppm	+2.47	-0.06	<10.0
E3-A12-S16	1 ppm	+0.85	-0.18	<1.0
E3-A12-S16	10 ppm	+2.48	-0.18	<10.0
E3-A12-S17	1 ppm	+2.48	-0.18	<1.0
E3-A12-S17	10 ppm	+2.48	-0.18	<10.0
E3-A12-S18	1 ppm	+2.47	-0.18	<1.0
E3-A12-S18	10 ppm	+2.48	-0.18	<10.0
E3-A12-S19	1 ppm	+2.48	-0.02	<1.0
E3-A12-S19	10 ppm	+2.47	-0.02	<10.0
E3-A12-S20	1 ppm	+2.47	-0.02	<1.0
E3-A12-S20	10 ppm	+2.47	-0.02	<10.0

NR = Not recorded. The actual instrument readings for E3-A12-S01 through S06 were not recorded, however, the fact that E3-A12-S01 had a positive reading (indicating no detectable level of PCBs) and E3-A12-S02 through S06 had a negative reading (indicating the presence of PCBs) was recorded.

Source: Ecology and Environment, Inc. 1994.

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Table 4-3 FIELD TEST RESULTS FOR PCB SCREENING OF SUBSURFACE SOIL SAMPLES

Site ID	Depth (feet)	Standard	Reading	Standard Reading	Conclusion
E3-A12-B01	4 4	1 ppm	+2.47	-0.02	<01
E3-A12-B01		10 ppm	+2.47	-0.02	<10
E3-A12-B01	14	1 ppm	+2.48	-0.02	<01
E3-A12-B01	14	10 ppm	+2.47	-0.02	<10
E3-A12-B02	4 4	1 ppm	+2.48	-0.00	<01
E3-A12-B02		10 ppm	+2.47	-0.00	<10
E3-A12-B02	14	1 ppm	+2.48	-0.00	<01
E3-A12-B02	14	10 ppm	+2.48	-0.00	<10
E3-A12-B03	4 4	1 ppm	+0.18	-0.02	<01
E3-A12-B03		10 ppm	+0.57	-0.02	<10
E3-A12-B03	9	1 ppm	+0.46	-0.02	<01
E3-A12-B03		10 ppm	+2.47	-0.02	<10
E3-A12-B04	4 4	1 ppm	-0.78	-0.01	>01
E3-A12-B04		10 ppm	-0.78	-0.01	>10
E3-A12-B04	9	1 ppm	+2.47	-0.01	<01
E3-A12-B04		10 ppm	+0.09	-0.01	<10

Source: Ecology and Environment, Inc. 1994.

				Cilcillical Sullin	nary Keport For			Part 1 of 2
Site Type: WIPE	PE			Building T104 Units: U	Building T104 Wipe Samples Units: UG/100 cm²			
		· Site ID	E4-P36-I01	E4-P36-I01	E4-P36-I02	E4-P36-103	E4-P36-I04	E4-P36-I05
		Field Sample ID	ID3601X1	IX3605X1	IX3602X1	IX3603X1	IX3604X1	IX3605X1
		Sample Date	04/26/94	04/26/94	04/26/94	04/26/94	04/26/94	04/26/94
Test	Parameter.							
TCL Pest	PCB-1254		< 0.015	< 0.015	< 0.015	< 0.015	2.00	< 0.015
	PCB-1260		0.063	0.140	0.035	0.035	< 0.300	0.082

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

(Note: No Background level comparisons available for wipe samples)

B= Attributable to field or laboratory contamination.

C= Confirmed on second column, U= Unconfirmed.

K= Result bias high. R= Result rejected.

L= Result bias low. R= Result rejected.

File Type: CBI Site Type: WIPE	BI 7IPE			Chemical Summary Report For Building T104 Wipe Samples	nary Report For Wipe Samples			Part 2 of 2
				Units: U	JG/100 cm ²			
ycle		Site ID	E4-P36-106	E4-P36-I07	E4-P36-I08	E4-P36-109	E4-P36-I10	
		Field Sample ID	IX3606X1	IX3607X1	IX3608X1	IX3609X1	IX3610X1	
		Sample Date	04/26/94	04/26/94	04/26/94	04/26/94	04/26/94	
Test	Parameter.							
TCL Pest	PCB-1254		< 0.015	0.200	< 0.015	< 0.015	< 0.015	
	PCB-1260		0.086	< 0.015	< 0.015	0.053	0.040	
			*					
<b>X</b>								

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below) (Note: No Background level comparisons available for wipe samples)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low. K= Result bias high. R= Result rejected

Date: 10/27/94	14		Table 4-5	e 4-5		Dana 1 of 7
File Type: CS	00		Chemical Summary Report	mary Report		Part 1 of 1
Site Type: PIT	ı		Septic Tank and Le	Septic Tank and Leach Field Samples		
			Units: UGG	IGG		
	Sample Type		Leach Field (Subsurface Soil)	e Soil)	Septic Tank Sludge	
	Site ID	E4-P36-P01	E4-P36-P01	E4-P36-P01	E4-P36-P02	
	Field Sample ID	PX360101	PX360102	PX360103	PX3602X1	
	Sample Date	04/27/94	04/27/94	04/27/94	04/27/94	
Test			3.0 ft	3.0 ft	3.0 ft	
TAL METAL		6320	8820	7900	2720	
	Antimony	< 0.500	2.02	0.310 Ji	23.7 !	
	Arsenic	3.35	5.03	5.43	5.86	
	Barium	29.1	27.5 !	21.6	114 !	
	Cadmium	< 0.500	< 0.500	< 0.500	42.3 !	
*	Calcium	< 500	241 J	346 J	18800 !	
	Chromium	86.6	14.2	16.8	493 !	
•	Cobalt	5.59	4.98	4.80	5.55 J	
	Copper	10.0	15.7	11.3	920 !	
	Iron	7390	9030	8030	7440	
	Lead	1.79	13.0	14.0	120	
	Magnesium	2030	1730	1260	2230 J	
	Manganese	67.4	8.69	74.1	140 !	
	Mercury	< 0.100	0.085 J	0.094 J	< 0.100	
	Nickel	7.81	7.27	80.9	36.8 !	
	Potassium	1410 !	1090	693 . 1	< 200	
	Selenium	< 0.200	0.192 L	< 0.200	2.48 L!	
	Silver	< 0.200	< 0.200	< 0.200	i 8.61	
	Vanadium	13.8	17.0	15.5	18.0	
	Zinc	< 21.2	140 !	150 i	3700 i	
TCL BNA	2-Methylphenol	< 0.330	< 0.330	< 0.330	80.0	
	Acenaphthene	< 0.330	< 0.330	< 0.330	10.0 J	
	Anthracene	< 0.330	< 0.330	< 0.330	50.0	
	Butyl benzyl phthalate	< 0.330	0.130 J	< 0.330	< 3.00	
	Naphthalene	< 0.330	< 0.330	< 0.330	10.0 J	

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected. != Exceeds Background (metals, pests only) .

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Date: 10/2//94 File Type: CSO Site Type: PIT	Sample Type	Field Sample ID	Sample Date	Test Parameter Depth		TCL Pest PCB-1254		TCL VOA 12DMB (o-Xylene)	134DMB (m- and or p-Xylenes)	Cis 1,2-Dichloroethylene		TPHC Total Petroleum Hydrocarbons								
	6 E4 B24 B01				< 0.330	< 0.020	< 0.020		< 0.005		< 0.005	< 20.0								
Chemical Summary Report Septic Tank and Leach Field Sa Units: UGG	Leach Field (Subsurface Soil)	PX360102	04/27/94	3.0 ft	< 0.330	< 0.040	0.190 CL	< 0.005	< 0.005	< 0.005	< 0.005	10.7 J								
Chemical Summary Report Septic Tank and Leach Field Samples Units: UGG	ce Soil)	PX360103	04/27/94	3.0 ft	< 0.330	< 0.020	0.116 CL	< 0.005	< 0.005	· < 0.005	< 0.005	15.6 J								
	Septic Tank Sludge	E4-F36-P02 PX3602X1	04/27/94	3.0 ft	10.0 J	CF CF CF	< 0.500	0.100 J	0.200 J	3.00	0.100 J	200000								
Page 2 of 2 Part 1 of 1																				

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

				Unit	Units: UGG		
		Site ID	E3-A12-S02	E3-A12-S03			
		Field Sample ID	SXA12021	SXA12031			
		Sample Date	09/02/93	09/02/93			
	Parameter.						
TCL Pest	Methoxychlor		0.018 JC!	0.092 U!			
	P,P-DDE		0.094 C	0.023 C			
	P,P-DDT		0.190 C	0.062 C			
	PCB-1260		0.163 C	0.261 C			
							•
	,						

!= Exceeds Background (metals, pests only) .

L= Result bias low. R= Result rejected.

J= Estimated value.K= Result bias high.

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

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Date: 10/27/94	94			Table	Table: 4-7			Page 1 of 2
File Type: CSO	SO		9	Themical Summary R	Chemical Summary Report For Surficial Soils	oils		1 of
Site Type: AREA	REA			Site	Site: P36			5
recy				Unit	Units: UGG			
		Site ID	E3-P36-S01	E3-P36-S01	E3-P36-S02	E3-P36-S03	E3-P36-S04	E3-P36-S05
pa		Field Sample ID	SD3601X1	SX3601X1	SX3602X1	SX3603X1	SX3604X1	SX3605X1
		Sample Date	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93
Test	Parameter.							3
TAL METAL	Aluminum		5740	2860	6640	0062	10500	13000
5	Antimony		5.39 !	6.09	4.33 !	< 0.500	< 0.500	< 0.500
	Arsenic		13.0	15.0 !	6.78	8.71	7.40	9.78
	Barinm		150 !	250 !	14.9	26.6	40.7	37.6
	Beryllium		0.248 J	0.285 J	0.231 J	0.386 J	0.449 Ji	0.499 Ji
	Cadmium		4.83	4.60 i	1.38 K!	0.228 BJ	2.90	0.377 BJ
	Calcinm		2070 !	2040 !	< 500	1000	872	465 J
	Chromium		35.4 !	40.5 !	23.8 !	15.2 !	16.7	16.8
	Cobalt		20.9 K!	21.3 K!	16.8 K!	7.43 K!	7.90 K!	7.92 K!
	Copper		93.8	94.9	36.9	15.6	46.3 !	14.5 !
	Iron		i 000 <i>L</i> 9	i 00085	i 00099	12000	14000	15000
	Lead		230 !	290 i	90.06	15.0	18.0	7.60
	Magnesium		3440 !	3130 !	1750	3120 i	2680 i	2440 !
	Manganese		362 !	331 i	209	146 !	143 !	120
٠	Nickel		45.9 !	41.2	30.1	14.0	12.8	12.9
	Potassium		1 098	i 066	636 !	1400 !	1700	1480
	Sodium		577	500	< 200	< 200	103 BJ	112 BJ
	Thallium		< 0.500	< 0.500	< 0.500	< 0.500	< 0.500	< 0.500
	Vanadium		32.1	30.6	25.5	22.7	22.5	23.6
	Zinc		1400 K!	1100 K!	1500 K!	150 K!	690 K!	55.7 K!
TCL BNA	Benzo(b)fluoranthene	anthene	< 3.00 L	< 3.00 L	< 0.330 L	< 0.330 L	< 0.330 L	< 0.330 L
	Butyl benzyl phthalate	hthalate	< 3.00 L	0.600 KJL	< 0.330 L	< 0.330 L	< 0.330 L	< 0.330 L

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

B= Attributable to field or laboratory contamination.

J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exceeds Background (metals, pests only) .

File Type: CSO			T TOTON				1 10 1 10 1
Site Tyne: ARFA	SO RFA	0	Chemical Summary Report For Surficial Soils Site: P36	sport For Surficial So P36	ils		
			Units	Units: UGG			
	Site ID	E3-P36-S01	E3-P36-S01	E3-P36-S02	E3-P36-S03	E3-P36-S04	E3-P36-S05
	Field Sample ID	SD3601X1	SX3601X1	SX3602X1	SX3603X1	SX3604X1	SX3605X1
	Sample Date	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93
Test	Parameter .						
TCL BNA	Fluoranthene	< 3.00 L	< 3.00 L	< 0.330 L	< 0.330 L	< 0.330 L	< 0.330 L
	Pyrene	< 3.00 L	< 3.00 L	< 0.330 L	< 0.330 L	< 0.330 L	< 0.330 L
TCL Pest	Endosulfan,B	0.047 C!	0.055 C!	0.017 C!	< 0.002	0.031 C!	0.002 JU
	P,P-DDD	0.059 U	0.058 U	0.016 U	0.010 U	0.013 U	0.004 U
	P,P-DDE	0.013 JU	0.038 JU	< 0.002	0.008 C	< 0.002	0.004 C
	P,P-DDT	0.480 C!	0.510 C!	< 0.002	0.037 C	< 0.002	0.037 C
	PCB-1260	1.90 C	2.20 C	0.610 C	< 0.020	1.20 C	0.090 C
	alpha-Chlordane	0.013 JC!	0.023 JC!	< 0.002	< 0.002	< 0.002	< 0.002
	gamma-Chlordane	0.051 C!	0.058 C!	0.033 U!	UC 0000	0.058 U!	0.002 JU
TOC	Total Organic Carbon	38600	42600	18100	19300	9710	17000
TPHC	Total Petroleum Hydrocarbons	096	920	122	30.1	83.1	42.6
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							٠

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

L= Result bias low.
R= Result rejected. != Exceeds Background (metals, pests only) . J= Estimated value. K= Result bias high.

4-28

9								
Date: 10/2//9	4			Tabl	Table: 4-7			1 . 6
File Type: CS	0			Chemical Summary L	Danort Ear Curfinial C	21:01		
Site Type: AREA	<b>LEA</b>			Site	Site: P36	SOIIS		Part 2 of 4
****	٠			Units	Units: UGG			
cycle		Site ID	E3-P36-S06	E3-P36-S07	E3-P36-S07	F3-P36-S08	F3_P36_C00	E2 D26 610
dos	Field S	Field Sample ID	SX3606X1	SX3607X1	SX3607X1	SX3608X1	SX3609X1	SX3610X1
		Sample Date	08/25/93	08/24/93	08/25/93	08/25/93	08/25/03	08/75/02
	Parameter.						00107100	00/23/93
TAL METAL	Aluminum		8580	12000		1 00801	14000	13000
	Antimony		< 0.500	< 0.500		0.532 RII	< 0.500 >	101
	Arsenic		6.17	7.97			689	
	Barium		27.1	38.1		43.0 1	58.8	20.7
	Beryllium		0.390 J	0.504 JI		17.17.0	0.00	30.5
	Cadmium		0.520 BJ!	0.794 BI			16.20	
	Calcium		985	547		204 124 DJ	13.5	1./4 K!
	Chromium		146 1	1 001		294	4/10	550 J
	Cobalt						16.61	73.3
	Consit		0.04 K.	7.90 K:		. 7.69 K!	8.34 K!	9.13 K!
	Copper	1	18.6	37.0		37.5 !	18.6	21.6
	Iron		13000	14000 !		18000 i	17000	20000
	Lead		25.0	50.0		70.0	20.0	450
	Magnesium		2800 i	2410 !		2400	3440	2340 1
	Manganese		163 !	134 !		125	170	178
	Nickel		11.9	13.3 !		14.1	15.5	13.8
	Potassium			1330 i		1700	2140	1410
	Sodium		201 KJ	170 KJ		181 KJ	110 BJ	122 RI
	Thallium		< 0.500	0.149 J		< 0.500	< 0.500	200
	Vanadium		23.0	30.8		31.1	30.1	30.4
	Zinc		410 K!	290 K!		830 KI	2300 KI	630 171
TCL BNA	Benzo(b)fluoranthene		< 0.330 L	0.082 JL		330 1	330	
rolog	Butyl benzyl phthalate		< 0.330 L	< 0.330 L		< 0.330 L	< 0.330	

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected. != I

It bias high. R= Result rejected. != Exceeds Background (metals, pests, TPHC only) .

File Type: CSO							
	2		Chemical Summary Report For Surficial Soils	Report For Surficial S	oils		Part 2 of 4
Site Type: AREA	REA		Site Units	Site: P36 Units: UGG			
	Site ID	E3-P36-S06	E3-P36-S07	E3-P36-S07	E3-P36-S08	E3-P36-S09	E3-P36-S10
	Field Sample ID	SX3606X1	SX3607X1	SX3607X1	SX3608X1	SX3609X1	. SX3610X1
	Sample Date	08/25/93	08/24/93	08/25/93	08/25/93	08/25/93	08/25/93
Fest	Parameter.						
CCL BNA	Fluoranthene	< 0.330 L	0.081 JL		< 0.330 L	< 0.330	
	Pyrene	< 0.330 L	0.090 JL		< 0.330 L	< 0.330	
TCL Pest	Endosulfan,B	0.004 U		0.072 C!	0.002 JU	< 0.002	0.019 U!
A	P,P-DDD	0.007 U		0.097 U!	0.022 C	< 0.002	0.063 U
	P,P-DDE	0.011 C		0.084 C	U 080 U	0.005 C	0.047 C
	P,P-DDT	< 0.002		0.940 C!	0.076 C	0.005 C	
	PCB-1260	0.169 C		3.50 C	0.166 C	< 0.020	0.750 C
	alpha-Chlordane	0.001 JU		< 0.002	0.002 JU	< 0.002	UC 1000
	gamma-Chlordane	0.003 U		0.072 U!	0.002 C	< 0.002	
TOC	Total Organic Carbon	21400	34600		16100	8430	58700
TPHC	Total Petroleum Hydrocarbons	25.3	101		110	46.0	64.0

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J= Estimated value. L= Result bias low.

K= Result bias high. R= Result rejected. != Exceeds Background (metals, pests only).

Date: 10/27/9	14		Table	Table: 4-7		Раде	re 1 of 2
File Type: CS	00	•	Chemical Summary F	Chemical Summary Report For Surficial Soils	oils	Pa	
Site Type: AREA	REA		Site	Site: P36		,	
			Units	Units: UGG			
	Site ID	E3-P36-S10	E3-P36-S11	E3-P36-S12	E3-P36-S12		
	Field Sample ID	SX3610X1	SX3611X1	SX3612X1	SXP36122		
ipei	Sample Date	09/03/93	08/25/93	08/25/93	12/02/93		
Test	Parameter.						
TAL METAL	Aluminum		9700	10700			
	Antimony		< 0.500	0.399 BJ			
	Arsenic		6.38	7.46			
	Barium		39.1 i	35.9			
	Beryllium		0.425 J	0.472 J!			
	Cadmium		0.411 BJ	0.713 B!			
	Calcium		740	999			
	Chromium		15.8	17.2 !			
	Cobalt		7.04 K!	9.63 K!			
	Copper		15.8	22.1			
	Iron		12000	15000 i			
	Lead		18.0	55.0			
	Magnesium		2770 !	2440 !			
	Manganese		132 !	221 !			
	Nickel		11.9	15.3 !			
	Potassium		1880 i	1210			
	Sodium		92.3 BJ	< 200			
	Thallium		< 0.500	< 0.500			
	Vanadium		24.2	36.3 !			
*	Zinc		70.2 K!	800 K!			
TCL BNA	Benzo(b)fluoranthene	< 0.330	< 2.00	< 8.00	< 2.00		
	Butyl benzyl phthalate	< 0.330	< 2.00	< 8.00	< 2.00		
cy e							

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!= Exceeds Background (metals, pests only) . R= Result rejected.

Site ID   E3-P36-S10   E3-P36-S1     Field Sample ID   SX3610X1   SX3611X1     Fammeter.	Date: 10/27/94	74		Table	Table: 4-7	•	Page 2 of 2
Site: P36   Units: UGG	File Type: C	09	0	Chemical Summary F	Report For Surficial S	oils	Part 3 of 4
Site ID   E3-P36-S10   E3-P36-S12   E3-P36-S12     Field Sample Date   Syx3610X1   SX361X1   S	Site Type: A	REA		Site	e: P36		
Field Sample ID   E3-P36-S10   E3-P36-S11   E3-P36-S12     Field Sample Date				Units	s: UGG		
Field Sample ID   SX3610X1   SX3611X1   SX3612X1		Site ID	E3-P36-S10	E3-P36-S11	E3-P36-S12	E3-P36-S12	
NAA   Fluoranthene   Control   Con		Field Sample ID	SX3610X1	SX3611X1	SX3612X1	SXP36122	
Parameter.   Parameter.   Parameter.   Parameter.     NA Fliotranthene		Sample Date	09/03/93	08/25/93	08/25/93	12/02/93	
Purenthene   < 0.330   < 2.00   < 8.00	Test	Parameter.					
Pyrene   Company   Compa	TCL BNA	Fluoranthene	< 0.330	< 2.00	< 8.00	< 2.00	
P.PDDD		Pyrene	< 0.330	< 2.00	< 8.00		
P.P-DDD         0.007 U           P.P-DDE         0.005 C           P.P-DDT         0.041 C           P.P-DDT         0.041 C           Apha-Chlordane         0.000 JU           gamma-Chlordane         0.000 JU           Total Organic Carbon         312           Total Petroleum Hydrocarbons         302	TCL Pest	Endosulfan,B		0.007 C!			
P.P-DDE		P,P-DDD		0.007 U	O.060 U		
P.P-DDT   P.P-DDT   P.P-DDT   P.P-DDT   P.P-DDT   P.P-1260   0.251 C   0.000 JU   0.000 JU   0.008 U!   0.00		P,P-DDE		0.005 C	0.031 C		
PCB-1260		P,P-DDT		0.041 C	0.670 C!		
alpha-Chlordane         0.000 JU           gamma-Chlordane         0.008 U!           Total Organic Carbon         312           Total Petroleum Hydrocarbons         302         18           Isolated Petroleum Hydrocarbons         18		PCB-1260		0.251 C	4.70 C		
Gamma-Chlordane		alpha-Chlordane		UC 0000	UC 1000		
Total Organic Carbon  Total Petroleum Hydrocarbons  302  302		gamma-Chlordane		0.008 U!	0.051 U!		
Total Petroleum Hydrocarbons 302	TOC	Total Organic Carbon		13800	31500		
	TPHC	Total Petroleum Hydrocarbons		302	1800		
	2						

!= Exceeds Background (metals, pests only).

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Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

File Type: CSO         Chemical Summary Report For Surficial Soils         Pair: Pair: Pair: CSO         Pair: Pair: CSO         Site 1D         Factors         Chemical Summary Report For Surficial Site 124         Chemical State Indication         Chemical State Indication         Chemical State Indication         DEA-1296-S14         EA-1296-S14         EA-129	Date: 10/27/94	14		Table: 4-7	: 4-7			Page 1 of 1
Site D    E4-P56-S13   E4-P36-S14   E4-P36-S16   E4-P36-S17   E4-P36-S16   E4-P36-S17   E4-P36-S16   E4-P36-S17   E4-P36-S17   SX3616X1   SX3616X1   SX3617X1   SX3616X1   SX3617X1   SX3	File Type: C	30	0	Chemical Summary R	Leport For Surficial S	oils		-
Field Simple ID   E4-P36-S14   E4-P36-S15   E4-P36-S16   E4-P36-S17   E4-P36-S16		KEA		Site Units:	: P36 : UGG			
Test   Parameter   Sample Date   O472594   O	vcled	Site ID	E4-P36-S13	E4-P36-S14	E4-P36-S15	E4-P36-S16	E4-P36-S17	E4-P36-S18
Test Sample Date 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/25/94 04/2	d pa	Field Sample ID	SX3613X1	SX3614X1	SX3615X1	SX3616X1	SX3617X1	SX3618X1
TCL Pest   Parameter   Param	aper		04/25/94	04/25/94	04/25/94	04/25/94	04/25/94	04/25/94
TCL Pest PCB-1254 < 1.00 < 0.080 < 0.0200 < 0.0400		Parameter.						
PCB-1260   6.30 CL   0.820 CL   < 0.020   < 0.0400   < 0.0400	TCL Pest	PCB-1254	< 1.00	< 0.080	< 0.200	< 0.020	< 0.040	11
TPHC Total Petroleum Hydrocarbons 460 442 414 18.3 J < 20.0  TPHC Total Petroleum Hydrocarbons 460 442 41.4 18.3 J < 20.0  TPHC Total Petroleum Hydrocarbons 460 442 41.4 18.3 J < 20.0  TPHC Total Petroleum Hydrocarbons 460 442 41.4 18.3 J < 20.0  TPHC TOTAL PETROLEUM HYDROCARDON 460 41.4 18.3 J < 20.0		PCB-1260		0.320 CL	0.820 CL	< 0.020	< 0.040	
	TPHC	Total Petroleum Hydrocarbons	460	442	41.4	18.3 J	< 20.0	152
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Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

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C= Confirmed on second column, U= Unconfirmed.

. R= Result rejected. != Exceeds Background (metals, TPHC only) .

File Type: CSO	0		Chemical Summary Report For Surficial Soils	Report For Surficial S	oils		Part 1 of 1
Site Type: AREA	<b>ZEA</b>		Site Units	Site: P37 Units: UGG			
	. Site ID	E3-P37-S01	E3-P37-S02	E3-P37-S03	E3-P37-S04	E3-P37-S05	E3-P37-S06
	Field Sample ID	SX3701X1	SX3702X1	SX3703X1	SX3704X1	SX3705X1	SX3706X1
	Sample Date	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93	08/25/93
Test	Parameter.						
TAL METAL	Aluminum	8700	8300	0688	7710	6270	5390
	Arsenic	5.52	7.09	7.35	5.94	6.54	5.80
	Barium	15.6	13.3	12.8	13.2	12.4	9.62
	Beryllium	0.312 J	0.277 J	0.282 J	0.269 J	0.236 J	0.147 J
	Calcium	< 500	< 500	< 500	359 J	342 J	< 500
	Chromium	13.2	11.6	17.1 i	6.11	9.53	9.34
	Cobalt	6.04 K	5.51 K	5.81 K	5.36 K	4.99 K	4.84 K
	Copper	9.85	7.91	7.74	9.46	6.82	7.34
	Iron .	10000	. 0006	10100	0686	7480	. 8360
	Lead	18.0	18.0	18.0	20.0	7.73	17.0
	Magnesium	1900	1620	1920	1700	1540	1590
	Manganese	167	105	123 !	122	110 i	122
	Nickel	12.5 !	10.8	13.3	10.4	9.02	9.82
	Potassium	516 K	433 K	442 K	551 K	526 K	491 K
	Vanadium	15.8	14.3	16.3	14.7	9.01	11.5
	Zinc	130 K!	72.1 K!	93.4 K!	130 K!	23.1 K	62.5 K!
TCL BNA	Bis(2-ethylhexyl)phthalate	0.150 J	< 0.330	0.046 J	1.30	< 0.330 L	0.160 JL
TCL Pest	Endosulfan,B	0.001 JU	< 0.002	< 0.002	0.002 C	< 0.002	< 0.002
	P,P-DDD		0.052 C	0.021 C	0.015 C	0.004 C	0.021 C
	P,P-DDE	0.057 C	0.057 C	0.010 C	0.006 C	0.001 JU	0.017 C
	P,P-DDT	0.140 C	0.160 C	0.072 C	0.063 C	0.021 C	0.081 C
TOC	Total Organic Carbon	12000	24100	14100	17000	12300	8560
ТРНС	Total Petroleum Hydrocarbons	58.0	55.8	87.6	34.1	86.0	27.5
				The second secon	The second secon		

B= Attributable to field or laboratory contamination. C=Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exc

R= Result rejected. != Exceeds Background (metals, pests only) .

Page 1 of 1 Part 1 of 2		2-B03	0301	0/93	) ft.	003														
Page		E3-A12-B03	BX120301	08/1	4.0 ft.	> 0.0														
		E3-A12-B02	BX120202	08/11/93	9.0 ft.	< 0.001 L														
Soils		E3-A12-B02	BX120201	08/11/93	4.0 ft.	< 0.001 L														
: 4-9 port For Subsurface : A12	: UGG	E3-A12-B01	BX120102	08/11/93	9.0 ft.	< 0.001 L														
Table: 4-9 Chemical Summary Report For Subsurface Soils Site: A12	Units	E3-A12-B01	BX120101	08/11/93	4.0 ft.	< 0.001 L														
ס		E3-A12-B01	BD120101	08/11/93	4.0 ft.	< 0.001 L														
		Site ID	Field Sample ID	Sample Date	Depth															
94 SO ORE					Parameter	Endosulfan, A														
Date: 10/27/94 File.Type: CSO Site Type: BORE	recy	cled	ра	per		TCL Pest				4-:				eco	ology	y ar	nd e	Privi	ron	men

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low. K= Result bias high. R= Result rejected. !=

ias high. R= Result rejected. != Exceeds Background (metals, pests only).

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File Type: CS	0,0		ט	nemical Summary Re	port For Subsurface	Soils	Part	Part 2 of 2
Site Type: BORE	ORE			Site: A12 Units: UGG	: A12 : UGG			
		Ol child	E3 A12 B03	E2 A12 B04	E3 A13 B04			
		Field Sample ID	RX120302	RX120401	E3-A12-B04			
		Sample Date	08/10/93	08/11/93	08/11/93		-	
Test	Parameter		9.0 ft.	4.0 ft.	9.0 ft.			
TCL Pest	Endosulfan, A		< 0.001	< 0.001 L	0.001 BU			

!= Exceeds Background (metals, pests only) .

J= Estimated value. L= Result bias low. K= Result bias high. R= Result rejected.

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

4-36

Date: 10/27/94	77		Table	Table: 4-10			
File Type: CSO	08		Chemical Summary Report For Subsurface Soils	eport For Subsurface	Soils		Part 1 of 2
Site Type: BORE	ORE		Site	Site: P36		v	
recyc			Units	Units: UGG			
cled	Site ID	E3-P36-B01	E3-P36-B01	E3-P36-B02	E3-P36-B02	E3-P36-B03	E3-P36-B03
рај	Field Sample ID	BX360101	BX360102	BX360201	BX360202	BX360301	BX360302
per	Sample Date	08/05/93	08/05/93	08/02/93	08/05/93	08/13/93	08/13/93
Test	Parameter Depth	4.0 ft.	14.0 ft.	4.0 ft.	14.0 ft.	4.0 ft.	9.0 ft.
TAL METAL	Aluminum	11000	5700	0026	2600	0066	0059
	Arsenic	4.25	3.83	4.84	2.84	7.20	5.71
	Barium	46.5 !	23.4	43.9 !	23.4	47.5 !	29.2
	Beryllium	0.454 J!	0.254 J	0.473 J!	0.262 J	0.398 J	0.298 J
	Cadmium	1.77.1	0.421 J	64.3	0.417 J	< 0.500	< 0.500
	Calcium	089	807	504 J	795	857	1350 !
	Chromium	19.2 K!	10.6 K	14.7 K!	10.5 K	17.3	12.6
	Cobalt	7.71	4.56	6:36	4.19	1.77.1	5.66
	Copper	12.3	17.8 i	14.4	8.47	15.6	11.7
	Iron	15000 !	9000	14000 !	9500	15000 !	12000
	Magnesium	3650 !	1840	2290	1500	2930 i	1890
	Manganese	140 !	92.1	160	120 !	163	120 !
	Nickel	14.7 J!	7.88 J	10.1 J	6.81 J	13.5 Ji	10.6 J
	Potassium	2640 !	1460	i 0261	1190 i	2390 i	1700
	Thallium	0.204 J	< 0.500	0.182 J	< 0.500	0.233 J	0.148 J
	Vanadium		13.8	19.8	11.8	24.6	19.6
	Zinc	24.6 K	13.2 K	21.6 K	24.3 K	76.2	28.8
TCL BNA	Di-n-octyl phthalate	0.120 J	< 0.330	< 0.330	< 0.330	< 0.330	< 0.330
TOC	Total Organic Carbon					4450	2090
TPHC	Total Petroleum Hydrocarbons	< 20.0	< 20.0	< 20.0	< 20.0	12.8 J	15.2 J
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B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. K= Result bias high.

L= Result bias low.
R= Result rejected. != Exceeds Background (metals, pests only) .

File Type: CSO Site Type: BORE  Test Parameter  TAL METAL Aluminum  Arsenic  Barium  Beryllium  Cadmium  Calcium	Site ID Field Sample ID Sample Date Sample Date Let Depth Um III III IIII IIII IIII IIII IIII II	E3-P36-M01 BX3601X1 08/05/93 9.0 ft.	E3-P36-M02 E786 BX3602X1 BX3602X1 E786 BX3602X1 E798 08/06/93	Chemical Summary Report For Subsurface Soils Site: P36 Units: UGG E3-P36-M02 E3-P36-M03	ioils	Part 2 of 2
Site Type: BORE  Fest Paramete TAL METAL Aluminu Arsenic Barium Barium Cadmiun Cadmiun	Field Sampl		Site: Units:	P36 UGG E3-P36-M03		
	Field Sampl		Units:  E3-P36-M02  BX3602X1  08/06/93  9.0 ft.	UGG E3-P36-M03		
	Field Sampl	E3-P36-M01 BX3601X1 08/05/93 9.0 ft.	E3-P36-M02 BX3602X1 08/06/93 9.0 ft.	E3-P36-M03		
	Field Sampl	BX3601X1 08/05/93 9.0 ft.	BX3602X1 08/06/93 9.0 ft.			
	Sampl	08/05/93 9.0 ft.	08/06/93 9.0 ft.	BX3603X1		
		9.0 ft.	9.0 ft.	08/07/93		
				14.0 ft.		
Arsenic Barium Berylliun Cadmiun Calcium	m m					
Berylliur Cadmiur Calcium	m un					
Berylliun Cadmiun Calcium	m L L					
Cadmiun Calcium	m T U					
Calcium	um					
	mn					
Chromium						
Cobalt						
Copper						-
Iron						
Magnesium	ium					
Manganese	lese					
Nickel						
Potassium	mı					
Thallium	n					
Vanadium	ur					
Zinc						
TCL BNA Di-n-octy	Di-n-octyl phthalate					
	Total Organic Carbon	14300	13500	12700		
TPHC Total Pet	Total Petroleum Hydrocarbons					

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exceeds Background (metals, pests only) .

File Type: CSO	File Type: CSO	0	Chemical Summary Report For Subsurface Soils	ary Report For Subsurface	Soils		Page 1 of 1 Part 1 of 2
			Units	Site: F3/ Units: UGG			
ycled	Site ID	E3-P37-B01	E3-P37-B01	E3-P37-B02	E3-P37-B02	E3-P37-B03	E3-P37-B03
na	Field Sample ID	BX370101	BX370102	BX370201	BX370202	BD370302	BX370301
Der	Sample Date	08/09/93	08/09/93	08/06/93	08/06/93	08/16/93	08/16/93
Test	Parameter Depth	9.0 ft.	14.0 ft.	9.0 ft.	14.0 ft.	14.0 ft.	4.0 ft.
TAL METAL	Aluminum	2000	4300	3700	3900	6940	5230
	Arsenic	4.58 J	4.04 J	4.71 J	5.59 J	5.47 J	6.45 J
	Barium	21.1	23.2	17.2	17.5	35.5 !	16.0
	Beryllium	0.243 J	0.252 J	0.189 J	0.202 J	0.306 J	0.245 J
	Cadmium	0.471 J	0.407 J	0.336 J	0.376 J	< 0.500	< 0.500
	Calcium	457 J	1340 !	933	1030	i 0611	651
	Chromium	11.4 K	11.1 K	8.14 K	8.20 K	1 0.91	9.74
	Cobalt	60.9	6.31	4.14	3.82	8.02	4.92
	Copper	8.75	9.34	5.92	5.21	9.56	7.86
	Iron	8800	8100	9059	0029	12000	0668
	Lead	4.13 B	3.51 B	23.0	2.68 B	2.99 B	3.55 B
	Magnesium	1970	1640	1450	1440	i i 522	2000
	Manganese	110 !	129 !	76.7	69.4	i 151	95.9
	Nickel	11.3	14.0	6.30	6:29	21.8 i	10.3
	Potassium	1120	1090	832 !	884 i	1530 i	i 080I
	Vanadium		11.7	8.82	8.52	16.7	11.6
	Zinc	24.1 K	31.3	13.7 K	15.1 K	41.7	28.4
TCL BNA	Di-n-octyl phthalate	< 0.330	< 0.330	< 0.330 R	< 0.330 R	0.028 J	< 0.330
TOC	Total Organic Carbon	0799	2700			2070 J	3940
TPHC	Total Petroleum Hydrocarbons	19.7 J	27.6	17.7 J	17.5 J	< 20.0	12.9 J
ology							
and							
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ir-							

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

L= Result bias low. R= Result rejected. J= Estimated value. K= Result bias high.

!= Exceeds Background (metals, pests only) .

File Type: CSO Site Type: BORE	п п	D	Chemical Summary Report For Subsurface Soils Site: P37	port For Subsurface	Soils		Part 2 of 2
one type box			Sile				
			Units	Units: UGG			
	Site ID	E3-P37-B03	E3-P37-B04	E3-P37-B04	E3-P37-M01	E3-P37-M02	E3-P37-M03
	Field Sample ID	BX370302	BXP37041	BXP37042	BX3701X1	BX3702X1	BX3703X1
	Sample Date	08/16/93	12/01/93	12/01/93	08/06/93	08/07/93	08/09/93
Test	Parameter Depth	14.0 ft.	0.0 ft.	0.0 ft.	14.0 ft.	14.0 ft.	14.0 ft.
TAL METAL	u	9620					
	Arsenic	6.98 J					
	Barium	27.6					
	Beryllium	0.327 J					
	Cadmium	< 0.500					
	Calcium	975					
	Chromium	13.6					
	Cobalt	6.74					
	Copper	8.70					
	Iron	11500					
	Lead	3.77 B					
	Magnesium	2550 !					
	Manganese	129 i					
	Nickel	17.7					
	Potassium	1460 !					
	Vanadium	15.0					
	Zinc	35.6					
BNA	Di-n-octyl phthalate	< 0.330	< 0.330	< 0.330			
	Total Organic Carbon	3770 J			13300	6490	11900
ТРНС	Total Petroleum Hydrocarbons	13.2 J					
						5.	

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

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Date: 10/2/194	+						
File Type: CGW Site Type: WELL	3W ELL		Chemical Summary   Site	Chemical Summary Report For Groundwater Site: P36	ater		Part 1 of 3
			Units	Units: UGL			
	Site ID	E3-P36-M01	E3-P36-M01	E3-P36-M01	E3-P36-M01	E3-P36-M02	E3-P36-M02
	Field Sample ID	MFP36011	MFP36012	MXP36011	MXP36012	MDP36021	MFP36021
4	Sample Date	09/01/93	12/01/93	09/01/93	12/01/93	09/02/93	09/02/93
Fest	Parameter .	Local Background	Local Background	Local Background	Local Background		
<b>TAL METAL</b>	Aluminum	23.6 BJ	20.2 BJ	84000	26000	3450	24.2 BJ
	Antimony	4.88 BJ	4.65 BJ	< 5.00 J	< 5.00	< 5.00 J	< 5.00
	Arsenic	< 2.00	1.31 J	35.2	27.0	2.71	< 2.00
	Barium	6.73 J	7.75 J	561 J	191	32.5 J	5.36 J
	Beryllium	< 5.00	< 5.00	3.96 J	1.12 J	< 5.00	< 5.00
	Cadmium	< 5.00	< 5.00	3.34 J	< 5.00	< 5.00	< 5.00
	Calcium	5290	6400	14400	9750	2510	1970
141	Chromium	< 10.0	< 10.0	208	73.4	7.44 J	4.00 Ji
	Cobalt	. < 10.0	< 10.0	65.8	18.7	2.82 J	< 10.0
	Copper	< 10.0	4.37 J	182	54.3	5.38 J	< 10.0
	Iron	17.7 BJ	13.5 BJ	00098	36000	4020 K	21.8 BJ
	Lead	< 5.00	< 5.00	24.0	18.2	3.53 J	< 5.00
	Magnesium	874	606	26200 J	7620	1280 J	486 J
	Manganese	124	66.2	1200	424	153	901
	Nickel	< 10.0	18.2	991	9.68	< 10.0	< 10.0
	Potassium	1170	1430 B	22000	6990 K	1980	1250 !
	Selenium	< 2.00	< 2.00	< 2.00 J	1.41 J	< 2.00 J	< 2.00
	Sodium	0996	12300	14000	12200	7250	7220
	Vanadium	< 10.0	< 10.0	187	47.9	6.98 J	< 10.0
	Zinc	13.6 BJ	22.4 K	180	9.69	60.7 K	5.75 BJ
CCL BNA	Bis(2-ethylhexyl)phthalate			< 10.0	< 10.0	< 10.0	
	Diethyl phthalate			< 10.0	48.0	< 10.0	
TPHC	Total Petroleum Hydrocarbons			217 J	266 BJ	< 2000	

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)
! = exceeds range for metals, TPHC found in local background well (E3-P36-M01)

L= Result bias low. J= Estimated value.

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

R= Result rejected. K= Result bias high.

File Type: CGW Site Type: WELL	,		Chemical Summary	Chemical Summary Report For Groundwater	ater		Part 2 of 3
Site Type: WEL			-	200			
			Sit	Site: P36			
			Uni	Units: UGL			
	Site ID	E3-P36-M02	E3-P36-M02	E3-P36-M02	E3-P36-M02	E3-P36-M03	E3-P36-M03
	Field Sample ID	MFP36022	MHP36021	MXP36021	MXP36022	MFP36031	MFP36032
	Sample Date	12/01/93	09/02/93	09/02/93	12/01/93	09/02/93	12/01/93
Test	Parameter.						
TAL METAL	Aluminum			4050	1190	69.5 B	19.4 BJ
7	Antimony	4.75 BJ	8.73 B	2.07 J!	< 5.00	4.30 BJ	< 5.00
•	Arsenic	1.32 Ji	< 2.00	3.92	1.84 J	< 2.00	1.01 J
	Barium	< 10.0	4.73 J	35.4 J	15.6	7.65 J	6.54 J
	Beryllium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
	Calcium	2180	2060	2450	3630	2930	2750
	Chromium	< 10.0	< 10.0	6.71 J	< 10.0	< 10.0	< 10.0
,	Cobalt	< 10.0	< 10.0	4.47 J	< 10.0	2.20 Ji	< 10.0
	Copper	< 10.0	< 10.0	8.04 J	5.90 J	< 10.0	< 10.0
	Iron	< 25.0	< 25.0	5040 K	1390	13.5 BJ	31.1 B
	Lead	< 5.00	< 5.00	< 5.00	3.69 BJ	< 5.00	< 5.00
	Magnesium	500 J	493 J	1460 J	855	807	800
	Manganese	85.7	104	155	114	224 !	167
	Nickel	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0	< 10.0
	Potassium	1210 B	1220	2040	1640 B	f 998	1140 B
	Selenium	< 2.00	< 2.00	< 2.00 J	< 2.00	< 2.00	< 2.00
	Sodium	5330 B	7140	0289	5300 B	5870	8600 K
	Vanadium	< 10.0	3.58 J	10.4	< 10.0	< 10.0	< 10.0
	Zinc	4.73 BJ	18.7 BJ	24.0 B	25.4 K	12.4 BJ	4.90 BJ
TCL BNA	Bis(2-ethylhexyl)phthalate			< 11.0	< 10.0		
	Diethyl phthalate			< 11.0	< 10.0		
TPHC	Total Petroleum Hydrocarbons			< 2000	287 BJ		

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Date: 10/27/	Date: 10/27/94		Table: 4-12		Page 1 of 1
File Type: CGW	MD		Chemical Summary Report F	For Groundwater	
Site Type: W	VELL		Site: P36		
raci			Units: UGL		
ycle	Site ID	E3-P36-M03	E3-P36-M03		
d na	Field Sample ID	~	MXP36032		
	Sample Date	09/02/93	12/01/93		
	Parameter.				
TAL METAI	C Aluminum	13000	12000		
	Antimony	< 5.00 J	< 5.00		
	Arsenic	11.0	9.55		
	Barium	86.4 J	73.5		
	Beryllium	0.546 J	0.533 J		
	Cadmium	2.70 J	< 5.00		
	Calcium	6730	5540		
	Chromium	26.1	20.4		
	Cobalt	15.4	12.9		
	Copper	22.6	22.8		
	Iron	21000 K	21000		
	Lead	6.07	5.58 K		
	Magnesium	f 0855	4980		
	Manganese	553	414		
	Nickel	30.1	26.0		
*	Potassium	4220	4230 B		
	Selenium	< 2.00 J	< 2.00		
	Sodium	7040	9140 K		
	Vanadium	32.7	28.4		
	Zinc	54.3 B	44.7	c	
TCL BNA	Bis(2-ethylhexyl)phthalate	4.40 J	< 10.0		
	Diethyl phthalate	< 13.0	< 10.0		
ТРНС	Total Petroleum Hydrocarbons	< 2000	531 BJ		
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Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)
! = exceeds range for metals, TPHC found in local background well (E3-P36-M01)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low. K= Result bias high. R= Result rejected.

File Type: CGW				Table. +15			101
Site Type: W	GW		Chemical Summary I	Chemical Summary Report For Groundwater	iter		Part 1 of 3
	ELL		Site Units	Site: P37 Units: UGL			
	Site ID	E3-P37-M01	E3-P37-M01	E3-P37-M01	E3-P37-M01	E3-P37-M01	E3-P37-M01
	Field Sample ID	MDP37011	MFP37011	MFP37012	MHP37011	MXP37011	MXP37012
	Sample Date		09/02/93	12/01/93	09/02/93	09/02/93	12/01/93
Test	Parameter.						
TAL METAL	Aluminum	12000	15.5 BJ	22.7 BJ	20.8 BJ	11000	45000
	Antimony	1.81 J!	< 5.00	4.53 BJ	< 5.00	2.70 J!	< 5.00
	Arsenic	34.5	< 2.00	2.14!	< 2.00	29.2	29.4
	Barium	62.1	8.49 Ji	7.33 J	6.09 J	74.8	232
	Beryllium	0.475 J	< 5.00	< 5.00	< 5.00	0.547 J	1.76 J
	Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	1.35 J	< 5.00
	Calcium	4960	4070	4740	4060	4990	10800
	Chromium	16.3	< 10.0	< 10.0	< 10.0	19.1	54.0
	Cobalt '	18.4	< 10.0	< 10.0	< 10.0	16.1	. 29.9
	Copper	160	< 10.0	< 10.0	< 10.0	14.2	108
	Iron	1500 K	< 25.0	30.0 B	< 25.0	14000 K	55000
	Lead	6.54	< 5.00	< 5.00	< 5.00	5.38	19.9
	Magnesium	3580	658	1220	720	3450	12300
	Manganese	408	24.4	52.5	24.1	389	624
	Nickel	< 10.0	< 10.0	< 10.0	< 10.0	17.3	58.5
	Potassium	2610	647 J	1190 B	726 J	2520	У 0968
	Sodium	4100	3780	8890 K	3810	4140	11200 K
	Vanadium	22.3	< 10.0	< 10.0	< 10.0	21.1	81.1
	Zinc	113 K	65.7 B	6.03 BJ	78.5 B	144	98.1
TCL BNA	Bis(2-ethylhexyl)phthalate	< 10.0				< 10.0	< 10.0
ТРНС	Total Petroleum Hydrocarbons	< 2000				< 2000	1290 KJi

File Type: CGW	Date: 10/2//94	94		Table	Table: 4-13			Page 1 of 1
Site Type: WELL	File Type: C	GW		Chemical Summary	Report For Groundwa	ater		Part 2 of 3
The color of the	Site Type: W	ÆLL		Sit	e: P37			
Field Sample ID   E3-P37-M02   E3-P37-M02   E3-P37-M02   E3-P37-M03   E3-P37-M03				Unit	ts: UGL			
Telet Sample Date         MRP37021         MRP37022         MRP37023         MRP37023         MRP37031         MRD3103         MRD3103 </td <td>clec</td> <td>Site ID</td> <td>E3-P37-M02</td> <td>E3-P37-M02</td> <td>E3-P37-M02</td> <td>E3-P37-M02</td> <td>E3-P37-M03</td> <td>E3-P37-M03</td>	clec	Site ID	E3-P37-M02	E3-P37-M02	E3-P37-M02	E3-P37-M02	E3-P37-M03	E3-P37-M03
Table   Sample Date   Sample Sample Date	pa	Field Sample ID	MFP37021	MFP37022	MXP37021	MXP37022	MFP37031	MFP37032
Table   Parameter.   Paramete	per	Sample Date	09/01/93	12/01/93	09/02/93	12/01/93	09/01/93	12/01/93
TAL METAL         Aluminum         36.7         B         22.0         BI         7790         4190         < 25.0         20.6           Antimony         3.21         B1         < 5.00	Test							
Antimony   3.21 BJ   < 5.00   1.85 JI   < 5.00   6.32 B   6.79   6.34     Antimony   3.21 BJ   < 5.00   < 2.00   < 2.00   6.34   5.84   5.68   6.79     Barrium   10.2   < 1 < 1.00   6.0.3   3.68   < 2.00   < 5.00     Barrium   10.2   < 1 < 1.00   6.0.3   36.9   4.80 J   8.16     Cadmium   6.500   < 5.00   < 5.00   < 5.00   < 5.00   < 5.00   < 5.00   < 5.00     Cadmium   6.980   5180   82.00   6.310   3650   < 5.00   < 5.00     Calcium   6.980   5180   82.00   6.310   3650   < 5.00   < 5.00     Calcium   6.980   1.880   8.20   6.310   3650   < 5.00   < 5.00     Cabelt   6.100   6.100   6.100   1.3.3   5.00 J   6.100   < 10.0     Cobelt   6.100   6.100   6.100   6.200   6.200   6.200   < 6.200     Coper   6.100   6.100   6.200   6.200   6.200   6.200   6.200   6.200     Lead   6.500   6.500   6.200   6.200   6.200   6.200   6.200     Manganese   6.200   6.200   6.200   6.200   6.200   6.200   6.200     Column   Nickel   6.100   6.100   6.200   6.200   6.200   6.200   6.200     Codium   6.100   6.100   6.100   6.200   6.200   6.200   6.200     Codium   7.70   6.100   7.200   7.98   7.100   6.100     Codium   7.71   7.10   7.10   7.20   7.10   6.100   6.100     Codium   7.72   81   1.10   81   81.1   7.200   7.10   7.10   7.10     CLE BNA   Bis(2-cthylhexyl)phthalate   7.12   7.10   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100   7.100	TAL METAI				7790	4190	< 25.0	
Assenic         < 2,00         < 2,00         < 5,00         6,200         0,840           Barylium         < 10,2		Antimony		< 5.00	,	< 5.00		
Barlum         10.2 i         < 10.0         i         < 10.0         i         8.16           Cadmium         < 5.00		Arsenic	< 2.00	< 2.00	5.84	3.68	< 2.00	0.840 J
Beryllium         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10		Barium	10.2	< 10.0	60.3	30.9	4.80 J	
Cadmium         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00		Beryllium	< 5.00	< 5.00	0.349 J	< 5.00	< 5.00	< 5.00
Calcium         6980         1         5180         8920         6310         3650         4310           Chromium         < 10.0		Cadmium	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
Chromium         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.		Calcium	1 0869	5180	8920	6310	3650	4310
Cobalt         < 10.0         < 10.0         7.62         J         5.00         J         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         <		Chromium	< 10.0	< 10.0	13.3	9.76 J	< 10.0	< 10.0
Copper         < 10.0         4.32         J         10.8         8.02         J         < 10.0         < 10.0           Iron         43.7         B         11.5         BJ         9280         K         4480         < 25.0		Cobalt	< 10.0	< 10.0	7.62 J	5.00 J	< 10.0	< 10.0
Fron		Copper	< 10.0	4.32 J	10.8	8.02 J	< 10.0	< 10.0
Lead         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00         < 5.00 <td></td> <td>Iron</td> <td></td> <td></td> <td></td> <td>4480</td> <td>&lt; 25.0</td> <td></td>		Iron				4480	< 25.0	
Magnesium         1180         1         828         3510         1890         574         682           Manganese         42.7         9.84         B         186         79.8         20.1         4.48           Nickel         < 10.0		Lead	< 5.00	< 5.00	< 5.00		< 5.00	< 5.00
Manganese         42.7         9.84 B         186         79.8         20.1         4.48           Nickel         < 10.0		Magnesium	1180	828	3510	1890	574	682
Nickel         < 10.0         < 10.0         11.7         < 10.0         < 10.0           Potassium         1060         1120         B         2770         1860         B         662         J         1600           Sodium         3970         5480         B         4580         5590         B         3330         5000           Vanadium         4.73         J!         < 10.0		Manganese	42.7		186	79.8	20.1	000
Potassium         1060         1120         B         2770         1860         B         662         J         1600           Sodium         3970         5480         B         4580         5590         B         3330         5000           Vanadium         4.73         JI         < 10.0		Nickel	< 10.0	< 10.0	12.0	11.7	< 10.0	< 10.0
Sodium         3970         5480         B         4580         B         3330         5000           Vanadium         4.73         Ji         < 10.0	,	Potassium	1060		2770		662 J	
Vanadium         4.73         J!         < 10.0         15.6         5.20         J         < 10.0         < 10.0         < 10.0         < 10.0         Substant         < 10.0         B         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0         < 10.0 <th< td=""><td></td><td>Sodium</td><td>3970</td><td></td><td>4580</td><td></td><td>3330</td><td></td></th<>		Sodium	3970		4580		3330	
Zinc         17.2         BJ         11.0         BJ         81.1         K         30.4         K         108         B           TCL BNA         Bis(2-ethylhexyl)phthalate         < 10.0		Vanadium		< 10.0	15.6		< 10.0	< 10.0
NA         Bis(2-ethylhexyl)phthalate         < 10.0         < 10.0           Total Petroleum Hydrocarbons         < 2000		Zinc						71.9
TPHC         Total Petroleum Hydrocarbons         < 2000         1930	TCL BNA	Bis(2-ethylhexyl)phthalate			< 10.0	< 10.0		
logy and environm		Total Petroleum Hydrocarbons			< 2000			
and environm	ogy					,		
environm	and							
	l en							
	vire							

Site Type: WELL	ELL		Chemical Summary Report For Groundwater Site: P37	oundwater	Part 3 of 3
			Units: UGL		
	Site ID	ID E3-P37-M03	E3-P37-M03		
	Field Sample ID	_	MXP37032		
	Sample Date	late 09/01/93	12/01/93		
Test	Parameter.				
<b>TAL METAL</b>	Aluminum	16000	44000		
	Antimony	2.24 Ji	< 5.00		
	Arsenic	39.8 i	100		
	Barium	84.0	176		
	Beryllium	0.980 KJ	2.09 J		
	Cadmium	< 5.00	< 5.00		
	Calcium	5360	0096		
	Chromium	28.0	67.2		
	Cobalt	23.6	47.6		
	Copper	22.6	65.8		
	Iron	20000	62000		
	Lead	99.6	29.8 !		
	Magnesium	4910	12400		
	Manganese	206	1200 !		
	Nickel	28.5	619		
	Potassium	4040	9170		
	Sodium	4580	6140 K		
	Vanadium	31.4	81.1		
	Zinc	158	282 !		
TCL BNA	Bis(2-ethylhexyl)phthalate	2.50 J	< 10.0		
TPHC	Total Petroleum Hydrocarbons	ns < 2000	< 2000		

Date: 10/77/04			T-11-1	T-L1 4 14		11
Date. 10/2/19	<b>1</b>		Lable	: 4-14	<u> </u>	
File Type: CS	M	_	Chemical Summary R	Chemical Summary Report For Surface Waters	I I	Part 1 of 1
Site Type: POND	OND		Site	Site: P37		
			Unit	Units: UGL		
vcle	Site ID	D E3-P37-D01	E3-P37-D02	E3-P37-D03		
	Field Sample ID	O WXP37011	WXP37021	WXP37031		
	Sample Date	e 09/16/93	09/16/93	09/16/93		
Test	Parameter.					
TAL METAL	Aluminum	1 0902	156	1480 !		
	Arsenic	9.16	2.59	45.8 !		
	Barium	52.2 J!	7.70 J	34.7 J!		
	Beryllium	1.39 J	< 5.00	< 5.00		
	Calcium	7050 J	2260 J	3880 J		
	Chromium	8.52 JK!	< 10.0 K	< 10.0 K		
	Cobalt	7.51 Ji	< 10.0	10.2		
	Copper	6.27 J	< 10.0	3.76 J		
	Iron	6490	903	14000 !		
	Lead	23.2	< 5.00	11.4		
	Magnesium	1390	658	934		
	Manganese	192 J!	124 J	1700 Ji		
	Nickel	< 10.0	< 10.0	10.6		
	Potassium	1060	319 J	904 J		
	Sodium	4660	2880	4700		
	Vanadium	9.51 Ji	< 10.0	6.05 Ji		
	Zinc	46.5	20.4	28.9 i		
TCL BNA	Bis(2-ethylhexyl)phthalate	1.40 J	24.0	< 10.0		
						T
envi						

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below)

B= Attributable to field or laboratory contamination. C= Confirmed on second column, U= Unconfirmed.

J= Estimated value. L= Result bias low.
K= Result bias high. R= Result rejected. != Exce

R= Result rejected. != Exceeds Background (metals, pests, TPHC only) .

Date: 10/27/94	94			Table: 4-15	4-15	٦	C JU
File Type: CSE	SE			Chemical Summary	Chemical Summary Report For Sediments	Part 1 of	of 1
Site Type: POND	ONC			Site	Site: P37		
				Units	Units: UGG		
		Site ID	E3-P37-D01	E3-P37-D02	E3-P37-D03		
	Field S	Field Sample ID	DXP37011	DXP37021	DXP37031	-	
	San	Sample Date	09/16/93	09/16/93	09/16/93		
Test	Parameter.						
TAL METAL	, Aluminum		3910	4870	4630		
	Antimony		< 0.500 L	< 0.500	1.72 JL!		
	Arsenic		8.72 !	3.01	37.4 !*		
	Barium		23.1 J	17.1	72.9 !*		
	Beryllium		0.734 JL!*	0.217 JL!	1.09 JL!*		
	Cadmium		0.744 BJ	0.576 BJ	2.50 KJ!*		
	Calcium		3170 !	306 J	4650 !*		
	Chromium		5.91 J	10.1	7.81 J		
	Cobalt		3.56 J	4.71	25.3 !*		
	Copper		7.39 L!	4.25 L	15.4 L!*		
	Iron		5070	8730 !	26500 !*		
	Lead		20.3	3.22	39.2 !		
	Magnesium		362 J	203000 !	832 J		
	Manganese		203 i*	115 !	i* 1680		
	Nickel		6.50 !	9.23 !	20.7 !		
	Potassium	•	< 20000	888	373 KJ		
	Selenium		0.852 JL!*	< 0.200	< 0.200 L		
	Thallium		< 0.500	0.093 J	< 0.500		
	Vanadium		6.50 J	11.4	21.8 !		
	Zinc		42.1 JL!	32.6 J!	72.9 Ji*		
TCL BNA	Fluoranthene		< 0.330	< 0.330	0.290 J		
	Pyrene		< 0.330	< 0.330	0.310 J		
TCL Pest	Endosulfan,B		< 0.002	0.001 JC!	< 0.002		
	Endrin		0.024 JC!*	0.005 KU	0.540 JU!*		10
	Heptachlor Epoxide			< 0.002	0.114 C!*		
	P,P-DDE		0.097 C!*	0.007 U!	0.345 Ci*		
	alpha-BHC		< 0.002	< 0.002	0.027 Ci*		

Source: USAEC IRDMIS Level 3/E & E, 1994 - Codes following values indicate data useability. (see below) != Exceeds Background Stream Levels (metals, pests, TPHC only) *= Exceeds Background Pond Level (metals B= Attributable to field or laboratory contamination.

C= Confirmed on second column, U= Unconfirmed.

*= Exceeds Background Pond Level (metals, pests only) - Only for P37-D01 and P37-D03 L= Result bias low. J= Estimated value. K= Result bias high.

R= Result rejected.

Date: 10/27/94	7/94		Table:	4-15		Page 2 of 2
File Type: CSE	CSE		Chemical Summary	Report For Sedimen	nts	Part 1 of 1
Site Type:	POND		Site	Site: P37 Units: UGG		
recy						
clec	Site ID	E3-P37-D01	E3-P37-D02	E3-P37-D03		
ра	Field Sample ID	DXP37011	DXP37021	DXP37031		
iper	Sample Date	09/16/93	09/16/93	09/16/93		
Test	Parameter.					
TCL Pest	gamma-Chlordane	*iOf 2000	0.002 JU!	0.190 Ci*		
TCL VOA	Toluene	0.030	< 0.005	< 0.005		
TOC	Total Organic Carbon	254000	10800	372000		
TPHC	Total Petroleum Hydrocarbons	< 20.0	< 20.0	174 !		
7						
10						
			4			
ecc						
olog						
gy a						
nd						
env						
iro						
nn						
len						

*= Exceeds Background Pond Level (metals, pests only) - Only for P37-D01 and P37-D03 L= Result bias low. J= Estimated value. K= Result bias high. = Exceeds Background Stream Levels (metals, pests, TPHC only) B= Attributable to field or laboratory contamination.

C= Confirmed on second column, U= Unconfirmed.

R= Result rejected.

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#### 5. CONTAMINANT FATE AND TRANSPORT

The fate and transport of chemicals in the environment is dependent both on properties of the contaminants and on characteristics of the environment. In general, the contaminant's properties dictate the fate of the chemical (i.e., in which phase(s) it will reside.) The characteristics of the environment, on the other hand, are primarily responsible for the potential transport mechanisms. There are certainly exceptions to this generality; for example, the organic content of the soil (an environmental characteristic) has an effect on how strongly certain organic compounds will sorb onto the solid phase (a potential fate).

The following two sections summarize potential fate and transport mechanisms in general. Section 5.3 is a more in-depth discussion of the contaminants of potential concern (COPCs) at Site A12/P36/P37.

## 5.1 POTENTIAL CONTAMINANT FATES

There are four phases at Site A12/P36/P37 in which a contaminant can reside in the environment. It can be found in the atmosphere or soil gas as a vapor. It may be dissolved in the aqueous phase, either in underlying groundwater or in surface water bodies such as Marlboro Brook. It can sorb onto solid particles, such as unsaturated soil, aquifer solids, or airborne particulates. Finally, it may exist in its own phase, either in the solid or liquid form. An examination of the physical and chemical properties of each contaminant can help in predicting in which phase(s) it is likely to be found. Contaminant transport can then be deduced from an understanding of the site characteristics. The following section summarizes the transport possibilities at Site A12/P36/P37.

#### 5.2 TRANSPORT MECHANISMS AT SITE A12/P36/P37

Contamination at Site A12/P36/P37 was probably introduced into the environment through the surficial soils (see Section 5.3). However, a variety of processes could redistribute the contaminants between phases, which may increase the possibility of transport. From the surface soils, volatile compounds tend to partition to the atmosphere, essentially removing them from other media of concern. Strongly sorbing compounds would bind to surficial particles, but could still be mobilized as suspended particulate matter in surface flow after large rainfall events. Soluble components can be mobilized in the aqueous phase, both in surface water and groundwater. Surface water in the area flows northeast, first around Building T104, then through the PCB spill/remediation area and around Building T106, before draining into Marlboro Brook. Soluble contaminants may reach the saturated zone via infiltrating rainwater. From here they would flow with the groundwater. Groundwater also flows northeast, draining to Marlboro Brook and the surrounding wetlands.

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# 5.3 FATE AND TRANSPORT OF CONTAMINATION

Buildings T104 and T106 were built in 1958 by Raytheon, Inc. (Raytheon), which no longer maintains records describing activities conducted on site. However, likely activity included research and development of missile guidance and radar systems, the manufacture of electronic equipment, electromagnetic interference testing, parachute development, and general research. It is difficult to determine from this limited information what types of contamination may result, but the waste streams from these activities probably included organic compounds such as solvents and oils. Metals could also have resulted from the development of the electronic equipment. If the waste streams were released to the environment accidentally, it would probably be to the surficial soils. However, Building T104 had its own septic system and leach field. Therefore, routine disposal activity could have resulted in contamination being released directly to the subsurface soils, or possibly the groundwater. Furthermore, both buildings had adjacent USTs that were removed in 1988. It is possible that the USTs were leaky and that their contents were released to the subsurface. In particular, the 1,000 gallon tank at Building T106 was noted to be in poor condition, with a 1-inch hole in the bottom. Contamination was noted, and 16 cubic yards of soil were removed at the time of tank excavation.

Building T104 was also used during the early 1980s as a transformer collection and storage area. It may therefore be a source of PCBs. Beginning in 1983, an area east of Building T104 was used to temporarily stage the transformers, after they were removed from secure storage in Building T104. Removal contractors would then come to remove them from the Annex. In July 1985, it was noticed that a transformer that was currently staged there had leaked PCB-laden oil. It appeared that vandals shot bullets into one transformer. Approximately 100 to 200 gallons of oil were released onto an asphalt walkway. Some appeared to have seeped through cracks into the surficial soils. The spill was cleaned, and some soil removed as part of the remedial effort. If contamination is still present, it would likely be in surface soils that were missed during the remediation, or in deeper soils.

Although site sampling revealed the presence of a wide variety of contamination at Site P36/A12/P37, the purpose of this section is to discuss the fate and transport of those compounds that may have contributed significantly to site-related contamination. Therefore, only those contaminants identified by the Human Health Risk Assessment (HHRA) and the Ecological Risk Assessment (ERA) as being of concern are included in this chapter. The HHRA considered virtually every contaminant that was detected as a contaminant of potential concern (COPC). Only a few metals and pesticides that were not detected above background concentrations were not included in the COPC list (see Section 6). However, very few contaminants were identified by the HHRA as posing potentially significant risks; arsenic. beryllium, lead, and PCBs (1254 and 1260). In the ERA, it was decided to limit the COPC list to those contaminants to which ecological receptors may be highly sensitive. Therefore, before the ERA was conducted, the data were screened against background and various riskbased criteria; only those which exceeded both with sufficient frequency were considered COPCs. In addition, several metals were excluded from the COPC list because they are not considered site-related, or the risk-based criteria were not considered appropriate (see Section 7 for more detail). The following contaminants passed through the screening and were

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considered in the ERA: arsenic, cadmium, copper, lead, zinc, DDE, DDT, and PCB 1260. Of these, only cadmium, copper, lead, and zinc were found to exceed the acceptable risk level. Nevertheless, all of the ERA COPCs are discussed because they passed the screening. On the other hand, only those COPCs identified by the HHRA as posing potential risk are discussed, since virtually no screening was applied in creating its COPC list.

## 5.3.1 Organics

For organic constituents, it is useful to consider contaminant properties such as aqueous solubility  $(C_{i,aq})$ , Henry's constant (H), and the octanol-water partitioning coefficient  $(K_{ow})$ . In general, compounds with a high  $C_{i,aq}$  also have a high H. If in the groundwater, they are likely to be mobilized in the aqueous phase, perhaps slowly volatilizing into the soilgas. Once in the surface water, however, they will ultimately reach the atmosphere. Compounds with a large  $K_{ow}$  are usually not very soluble or volatile. They may exist primarily in their own phase, or may sorb onto organic rich soils and sediments. They will then be immobilized unless the solids themselves are transported as suspended solids or airborne particulates.

These three properties can be used to predict the fate of organic contaminants. To analyze sorption, an empirical relationship was developed by Karickhoff  $et\ al.$  (1979) relating the ratio of the concentration of a solute sorbed onto aquifer particles to the concentration of solute in solution. For solute i:

$$K_d = \frac{C_{i,solid}}{C_{i,og}} = (0.63 \times 10^{-6} \frac{m^3}{g})(k_{ow})(f_{oc})$$

where  $K_d$  = distribution coefficient  $C_{i, solid}$  = gram of solute sorbed per gram of solid  $C_{i, aq}$  = gram of solute dissolved per  $m^3$  of solution 0.63 x  $10^{-6}$   $m^3/g$  = empirically determined constant  $K_{ow}$  = octanol/water partitioning coefficient  $f_{oc}$  = mass fraction of organic carbon in solid.

The dimensions of this coefficient make it difficult to judge what would be considered strongly or weakly sorbing. It is more useful to consider a unit volume in the aquifer and calculate the ratio of contaminant mass sorbed onto solids to contaminant mass dissolved in groundwater in the volume. This is calculated by multiplying the distribution coefficient by several factors.  $P_6$  is the bulk density of aquifer solids, that is, the mass of solids per unit volume. If the porosity of the aquifer is n, then (1-n)/n is the ratio of the volume of aquifer solids to the volume of groundwater in the unit volume. Thus,

$$M = K_d \frac{P_6(1 - \epsilon)}{\epsilon} = \frac{mass \ i \ sorbed}{mass \ i \ dissolved}$$
 in the unit volume

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M, the mass distribution of solute i in the aquifer, essentially represents the tendency of the compound to exist in either sorbed or dissolved form. When M=1, then at equilibrium there will be equal amounts of solute sorbed and dissolved. Every time uncontaminated water enters the unit volume, half of the solute would desorb and enter solution. Because water is continuously moving through most aquifers, this would represent a mobile, non-sorbing contaminant. When M=100, one percent of the solute is dissolved at equilibrium. Then, as fresh water is introduced into the volume, only one percent of the solute would desorb. Still, the contaminant would not persist in the solids over the very long term, and this contaminant is considered moderately sorbing. Contaminants with  $M>10^4$  can be considered strongly sorbing. They would be expected to persist, essentially immobilized, sorbed to aquifer solids. Such compounds would also sorb strongly to sediments and surficial soils with sufficient organic content. However, they could be mobilized in these media either as suspended solids or airborne particulates.

A particularly useful representation of sorption tendency is derived from the model of contaminant flow through porous media. When sorption is accounted for in the model, the following "retardation factor" relates the groundwater velocity to the contaminant velocity (Tchobanoglous 1987):

$$R = \frac{V_{gr}}{V_{con}} = \frac{K_d P_b (1 + \epsilon)}{\epsilon}$$

where  $V_{gr}$  = average velocity of groundwater, and  $V_{con}$  = average velocity of contaminant front

The reciprocal of this term (1/R), therefore, represents the ratio of contaminant velocity to groundwater velocity (Freeze and Cherry 1979). That is, it is an estimate of how much the contaminant is slowed because of sorption effects. If a strongly sorbing compound  $(R > 10^4)$  is within the aquifer, then, as groundwater flows through an uncontaminated area, almost all of the dissolved portion would be expected to sorb out. Therefore, the contaminant itself will be essentially immobile. For a completely non-sorbing compound,  $K_d = 0$ , R = 1, and the contaminant moves with the same velocity as the groundwater. Contaminants with a retardation factor from 10 to 1,000 can be considered moderately to considerably sorbing. Those with R = 100 to 1,000 clearly will move much more slowly than groundwater. However, over the very long term, if groundwater movement is fast, then even these contaminants will exhibit some mobility.

To evaluate the tendency of a compound to volatilize, the Henry's constant is calculated for that compound. The dimensionless form of this constant is the ratio of the molar concentrations of the solute in vapor to that in solution, and is calculated as:

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$$H = \frac{P_i^{sat}}{C_i RT}$$

where  $P_i^{sat}$  = vapor pressure of solute i (atm)  $C_i$  = solubility of solute i (mol/L)

R = ideal gas constant =  $0.0821 \frac{atm \cdot L}{mol \cdot K}$ 

T = temperature (K)

For example, consider the case of a closed vessel with equal quantities of water and air. If, for a given compound, the dimensionless Henry's constant equaled one, then equal quantities of the compound would be dissolved and vaporized. Of course, in nature, if a compound is in the surface water, for example, there is virtually an infinite quantity of air in which to vaporize. For this compound, it could be assumed that all of it reached the vapor phase. These contaminants will be considered highly volatile. Contaminants with  $H = 10^{-2}$  are moderately volatile, and those with  $H < 10^{-5}$  are insignificantly volatile.

Literature values for the aqueous solubility, vapor pressure, and octanol/water partitioning coefficient of the organic contaminants of concern found at Site A12/P36/P37 are presented in Table 5-1. Henry's constants were calculated from the vapor pressure and solubility, and were made dimensionless using a temperature of 20°C (293 K). Mass distribution and retardation factors were calculated using  $P_b = 2.0 \times 10^6$  (Tchobanoglous 1987), v = 0.30 (Freeze and Cherry 1979), and organic content ( $f_{\infty}$ ) calculated from an average of 13 soil samples taken around Building T104. These values are also listed in Table 5-1.

### 5.3.1.1 Polychlorinated Biphenyls (PCBs)

PCB-1254 and 1260 were identified by the HHRA as posing potential risks in surface soils. In addition, the ERA identified PCB-1260 as a COPC in soils. These compounds are typically thought of as being immobile in most systems, sorbing strongly to solid particles, whether in surface soils, sediments or aquifer solids. As their physical/chemical properties indicate they are practically insoluble and have a considerable tendency to sorb. However, because these soils do not have a particularly high organic content (about 2.5 percent in an average of 13 soils samples at Building T104), the PCB's retardation factors are approximately 10 times lower than they would be in more highly organic sediments. Therefore, they could leach very slowly with infiltrating rainwater (ATSDR 1993). Furthermore, their Henry's constants indicate that they have a significant potential to volatilize from the aqueous phase. While sorbed to soils this tendency is attenuated considerably. Nevertheless, if PCBs will be removed from the soils at all, it will probably be due to volatilization.

			Table 5-1	5-1			
	PHYSI	CAL/CHEMI	CAL PROPERT	PHYSICAL/CHEMICAL PROPERTIES OF THE ORGANIC COPCS	RGANIC	COPCs	
Contaminant	Molecular Weight ^a g/mol	Aqueous Solubility ^a mg/L	Vapor Pressure ^a mmHg	Henry's Constant ^b [-]	Log Kow ^a [-]	Mass Distribution ^c M, [-]	Retardation Factor ^c R, [-]
DDE	318.03	0.12	0.12 6.5 x 10 ⁻⁶	9.42 x 10 ⁻⁴	7.00	7.35 x 10 ⁵	1.04 x 10 ⁶
DDT	354.49	0.0034	0.0034 5.5 x 10 ⁻⁶	3.14 x 10 ⁻²	6.19	1.14 x 10 ⁵	1.63 x 10 ⁵
PCB-1254	. 328	0.012	0.012 7.71 x 10 ⁻⁵	0.115	6.5	6.5 2.33 x 10 ⁵	3.32 x 10 ⁵
PCB-1260	375.5	2.7 x 10 ⁻³	2.7 x 10 ⁻³ 4.05 x 10 ⁻⁵	0.308	8.9	6.8 4.64 x 10 ⁵	6.65 x 10 ⁵

^a Source ATSDR, 1992 to 1993. ^b Calculated from vapor pressure and solubility. ^c Calculated using  $P_b = 2.0 \times 10^6 \, g/m^3$ ; n = 0.30;  $f_{oc} = 0.025$  (for PCBs) = 0.372 (for Heptachlor epoxide)

Source: Ecology and Environment, Inc. 1994.

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PCB compounds (particularly the heavier ones like 1254 and 1260) are not transformed quickly, either biotically or abiotically. In the vapor phase, the primary transformation mechanism is probably photolysis with hydroxy radicals, with a half-life on the order of months (ATSDR 1993). Biodegradation in soil and water is possible, both aerobically and anaerobically, but is also very slow. The heavier PCBs, again, are resistant to biotransformation.

Taken together, the following scenario for PCB fate and transport can be constructed. PCBs are most likely the result of the temporary storage and staging of transformers that was done at Building T104 in the early 1980s. This is indicated by their detection at very low levels in wipe samples inside the building. The highest detections were in surface soil samples in the northwest corner of the building. This may have been where transformers were unloaded from trucks into the building. The sample from the septic tank had a fairly large hits, and there were lower detections in samples under the leaching pipes. This suggests that PCB contaminated oils were disposed of through drains inside Building T104. The low detections in surface soils immediately around the building suggest that some oils may have leaked out of entrances. There were low-level hits in the surface soils taken at the PCB spill/remediation area; these are probably residual levels remaining from the spill that was discussed above.

Most of the PCBs became sorbed to the solid particles upon contact. PCB compounds tend to sorb strongly; however, because these soils are not highly organic, they may be susceptible to redistribution. The most significant mechanism is probably vaporization. When the soil is wet after rainfall events, a very low quantity of PCBs may dissolve; however, because of their large Henry's constants, it is more likely that they will volatilize than be transported in the aqueous phase. Of course, they can be mobilized with surface flow while attached to particulate matter. Soil samples taken downgradient of Building T104 do not show PCB contamination, indicating that this transport mechanism is probably not significant. In summary, the PCBs will remain in the surface soils, immobilized, for a long time. The primary removal mechanism will be vaporization, and there is little potential for mobilization in the aqueous phases.

# 5.3.1.2 Pesticides

DDT and DDE were identified by the ERA as a COPC in surface soils. Both of these compounds have been extensively studied, ultimately leading to the 1973 banning of their application in terrestrial systems. They have very low solubilities and strong tendencies to sorb, as is evident by retardation factors in the 10⁵ range. They are not expected to leach to groundwater or be mobilized in the aqueous phase. Rather, they are expected to remain sorbed to solid particles. Because these soils are not very highly organic, the tendency to sorb is somewhat attenuated. Nevertheless, they are likely to mobilize only with suspended particles in surface water flow. DDT and DDE have been observed to volatilize from both surface soils and surface waters. Their vapor pressures and Henry's constants are not very high, so the process is slow; however, vaporization is a potential removal mechanism from soils. Once in the atmosphere, they attach to small particulates, but wet deposition appears to

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be the dominant removal process. Therefore, they may travel over long distances in the atmosphere.

DDT and DDE are bioaccumulated in terrestrial and aquatic organisms. DDT is susceptible to photooxidation in air. Little degradation is observed in the aqueous phase since it tends to sorb onto sediments and particulates. In aerobic soils, DDT is biodegradable, with the primary transformation compound being DDE. DDE is more resistent to transformation.

Based on this discussion, the following fate and transport scenario can be constructed. DDT was probably applied as part of site-wide pest control. It would cover most surficial objects, including the surficial soils. From here, it would be expected to behave similarly to the PCBs. Namely, it will largely sorb to the soil particles, and remain immobilized. Over time, it will vaporize rather slowly, but this can be considered the primary removal mechanism. Because the surficial soils are exposed to oxygen, the DDT is slowly transformed to DDE, thereby explaining this compound's presence. DDE will not be degraded further, but will remain immobilized in the soils. It will also be removed very slowly by volatilization.

# 5.3.2 Inorganics

Metals can volatilize into the air, sorb onto particles, enter the aqueous phase or exist as an insoluble solid or liquid. However, their physical/chemical properties (H,  $C_{i,aq}$ ,  $K_{ow}$ ) depend on the oxidation states they are in, and on the type of complexes that exist for a given metal. These, in turn, are determined by the properties of the environment itself, such as pH, redox potential, and water quality. For example, lead can exist in three oxidation states, two of which, Pb(IV) and Pb(0), form solids that are so insoluble (PbO_{2(s)} and Pb_(s)) that virtually no other species exist. However, in most natural systems, Pb(II) is dominant and a variety of soluble compounds may form. Accurately predicting the existing form(s) of a metal in a given environment requires detailed knowledge of that environment's chemistry. Nevertheless, trends can be deduced from a more limited characterization. Unless otherwise noted, the information that appears below was found in the Toxicological Profiles, ATSDR, 1992 to 1993.

## 5.3.2.1 Arsenic

Arsenic was identified in the human health risk assessment as posing potential risk in soils, groundwater, and sediment. It was also identified in the ERA as a COPC in sediments. However, as discussed in Section 4, arsenic in soils and groundwater was not particularly elevated above background. The detections of arsenic in Marlboro Brook waters and sediments are unlikely to be related to the site, but may be related to other sites (such as P28 and P38) located near the headwaters of Marlboro Brook where arsenic was elevated in soils. Nevertheless, arsenic is discussed in this section due to its identification in the risk assessments.

Analysis of arsenic's transport in the environment is complicated considerably because its redox state can change frequently in common environmental conditions due both to

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chemical and biological transformation. Its ground state, the insoluble and sorbing As(0) is rarely observed. In soils where oxygen is present, the fully oxidized As(V) results, generally as arsenate (AsO₄³⁻), which forms insoluble salts with aluminum, barium, calcium, and iron. These will sorb to soil particles, and will be mobilized only with dust or as suspended particulates in surface flow. However, chemical redox reactions as well as microbial transformation can reduce arsenic to more mobile forms. For example, in slightly reducing conditions, the arsenate may be reduced chemically to arsenite (As⁽⁺³⁾O₃³⁻), or biologically to (CH₃)₂As⁽⁺³⁾O₂H through biological methylation. After large rain events, even the surficial soils could be slightly reducing. Methylated arsenic is considerably soluble, and if it reaches the saturated zone (possibly anaerobic), highly reducing conditions could further reduce the As(III) to As(-III), again through biomethylation. As⁽⁻³⁾(CH₃)₂ is soluble and could be transported in groundwater. Methylated arsenic is also considerably volatile. However, if it were to reach the atmosphere, it would probably be oxidized to As(V) (as arsenate) or As(III) (as arsenite), attach to particulates, and eventually drop out of the vapor phase. Nevertheless, biomethylation represents a possible mechanism for the transport of arsenic.

It appears that most of the arsenic is actually sorbed. Concentrations in soils and sediments correlate closely with organic carbon content. Groundwater samples provide additional evidence, as the concentration in filtered samples was approximately an order of magnitude lower than in unfiltered samples. It appears that the arsenic is largely bound up with particulate matter and is not present in the dissolved form. Any dissolved arsenic would flow with the groundwater, toward Marlboro Brook. However, it is difficult to link arsenic with any site activity, and its detection is fairly uniform throughout the site. For these reasons, it appears that the arsenic found at Site A12/P36/P37 is due to natural fluctuation, and not to site activities.

# 5.3.2.2 Beryllium

Beryllium was identified by the HHRA as posing potential risk in surface soils. Beryllium forms a divalent ion only and can therefore form only a limited number of compounds. In the atmosphere it can be found as BeO, which may be removed via wet and dry deposition. In aqueous systems, it generally precipitates as BeCO₃ or Be(OH)₂. Its concentration in sediment has been observed to be much higher than its concentration in water above the sediment. Therefore, it is either precipitated or sorbed, but probably not dissolved in the aqueous phase. It is not likely to be mobilized in solution. It sorbs strongly to soil particles as well, because it replaces other divalent ions which compete for sorption sites. Therefore, it is also unlikely to be mobile in soil.

Like arsenic, beryllium exceeded its background level in only a few samples. Also like arsenic, it is clearly sorbed to particulate matter. Groundwater samples indicate that the beryllium is sorbed to solids, and not dissolved in the water itself. Since its detection was so common and it cannot be linked to site activity, it appears that beryllium is present naturally in this area.

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#### 5.3.2.3 Cadmium

Cadmium was identified in the ERA as a COPC in soils. Like beryllium, cadmium exists only in the +2 oxidation state. It will generally be found as a hydrated ion (Cd²+ 6H₂O), but can also be bound up in organic complexes. It is fairly soluble as an ion in water, and is therefore more mobile than most heavy metals, particularly at low pH. The redox potential of the aqueous phase does not generally have a large effect on solubility because of cadmium's single oxidation state. Cadmium may be removed from solution via sorption to moist soils and sediments. This process may be assisted by cadmium-sensitive bacteria. Partitioning to air is not known to occur since cadmium and its related compounds have negligible vapor pressures. However, airborne particulates may contain cadmium. In particular, combustion processes may emit cadmium-sorbed particles which may reside in the atmosphere up to 10 days, travelling hundreds of miles. Cadmium was detected in only two samples, one from the septic system, and one from a subsurface soil sample at Building T104. It is likely to be sorbed to solid particles, but may be mobilized as discussed above. If it entered groundwater, it would flow with it, toward Marlboro Brook.

# 5.3.2.4 Copper

Copper was identified in the ERA as a COPC in soils. It can exist in the +1 or +2 oxidation state. When in the +1 state in the aqueous phase, only insoluble forms such as Cu₂S and CuCN are likely. In most aqueous environments, particularly if aerobic, copper will exist as Cu²⁺. There are several soluble species, such as Cu²⁺, Cu(HCO₃)⁺, and Cu(OH)₂, but in most natural waters, dissolved copper may be at very low concentrations. Dissolved copper will be complexed with colloids, precipitated as an insoluble solid, or sorbed to solids such as organic sediments, clays, or iron and manganese oxides. Therefore, it is not expected to be mobile in groundwater.

Similarly, in soil, copper will bind to organic matter, carbonate or clay material, and iron and manganese oxides. It sorbs more strongly to clay than most divalent ions such as zinc and cadmium. Therefore, it is not expected to leach into the groundwater. Copper complexes are not volatile, so atmospheric copper will be sorbed to particulates. They are usually found on sub-micron particles, which can remain in the atmosphere for weeks, travelling long distances before being removed by wet or dry deposition. Finally, copper complexes are not believed to bioconcentrate or biomagnify. Copper was detected in surface soils at a concentration nine times as high as background, and it is unlikely to mobilize in either the aqueous or vapor phases.

#### 5.3.2.5 Lead

Lead was identified in the HHRA as posing potential risks in soils and groundwater, and in the ERA as a COPC in soils and surface water. The physical chemistry of lead, and, in turn, its fate and transport in the environment, is difficult to analyze because of its variety of forms. In highly reducing conditions, Pb(0) predominates, and the insoluble Pb_(s) is virtually the only form. Groundwater systems may sometimes be anaerobic and reducing, and it is possible that elemental lead exists in the deeper subsurface where it would be mostly

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immobile. In highly oxidizing conditions, Pb(IV) predominates, and the insoluble  $PbO_{2(s)}$  results. However, most of the surficial environments are likely to exist in moderate redox conditions where lead will be found primarily as Pb(II).

The precise form of lead in soils is affected by pH, organic content, the presence of inorganic colloids, and several other soil characteristics. It may exist as a precipitate, as a chelate or within an organo-metallic complex. Regardless, it is likely to sorb strongly to soil particles and will not generally be transported in the aqueous phase. However, under acidic conditions (pH 4 to 6), in soils with a low organic content, significant leaching to groundwater is possible. In fact, in soft waters (without a high ionic content) of pH = 5.4. up to 500 µg/L lead may be in the dissolved form. Natural rainwater has a pH of about 5.5. so there could be some leaching of lead after rain events large enough to induce infiltration. However, rainwater also has a carbonate content due to atmospheric carbon dioxide (pCO₂ = 10^{-3.5}). In such situations, the dissolved lead content will probably be limited by lead carbonates, PbCO₃ and Pb₂(OH)₂CO₃, especially if the pH of the water rises after contacting the soil. Furthermore, most rainwater and groundwater does contain other anions such as hydroxides, sulfates, and phosphates, which will further limit dissolved lead concentration. Therefore, it is likely that lead will remain sorbed to particles, within both the vadose and saturated zones. However, lead could still be mobilized during significant surface runoff events while attached to suspended particulates.

Similarly, in air, most of the lead will be in the particulate form. Residence time is highly dependent on particle size, but much of the lead appears to be associated with large particles (>  $1\mu$ m), so lead may not be transported far. However, some organic, alkylated forms of lead may be both volatile and soluble. For examples, tetramethyl lead, formed through bioalkylation in anaerobic environments, has a vapor pressure of 26.0 mmHg at 20°C. However, tetramethyl and the moderately volatile tetraethyl lead are photolyzed when exposed to sunlight to the tri- and dialkyl forms, which are less volatile and more soluble. These compounds may have the opportunity to leach into the groundwater. Eventually, however, these compounds are converted to inorganic lead. Thus, while lead may be briefly mobilized into the vapor and aqueous phases through anaerobic microbial methylation, it is ultimately returned to inorganic forms that will likely become sorbed into the solid phase. Detections in groundwater at Site A12/P36/P37 were entirely in unfiltered samples, indicating that the lead is not dissolved. It was also detected in a surface water sample above background. However, it may also have been due to suspended particulates within the sample. It appears that no significant quantities of lead will be mobilized from Site A12/P36/P37.

#### 5.3.2.6 Zinc

Zinc was identified in the ERA as a COPC in surface water and soils. It exists primarily in the +2 oxidation state in the environment. In most situations, the zinc ion  $(Zn^{2+})$  is in the hydrated form, which generally partitions to iron and manganese oxides, clay minerals, and organic matter. Like most sorption processes, the extent is dependent on environmental factors such as pH, redox potential, concentrations of ligands, etc. However, zinc can be mobilized in the aqueous phase, particularly at low pH. On the other hand, in

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reducing environments and in the presence of hydrogen sulfide, zinc sulfide will precipitate out, thereby limiting its mobility.

In general, zinc will sorb onto a variety of particles. In anaerobic soils, zinc sulfide will reduce its mobility. However, in aerobic soils, soluble salts such as zinc chloride and sulfate will be mobile, although its solubility may be controlled by other salts. In the atmosphere, it is present as particulate matter, some of which are small and may be transported long distances before returning to the soil and aqueous phases through wet and dry deposition. Zinc is an essential nutrient, present in all organisms. Not surprisingly, it is found in a variety of organisms in concentrations much greater than ambient. As with the other metals, while it is possible for zinc to mobilize, it is more likely to be found sorbed to solid particles. Furthermore, it is almost certainly naturally-occurring and not related to site activity.

#### 5.4 CONCLUSIONS

Several PCBs, two pesticide compounds, and some metals were identified in the risk assessments as posing concern. The pesticides and PCBs have similar properties and may therefore exhibit similar fate and transport tendencies. In general they are immobile, sorbed to solid particles either in soils, sediments, or the aquifer matrix. They will not dissolve in the aqueous phase; if they repartition at all, it will be through volatilization to the atmosphere. Most likely, these compounds can be expected to remain immobilized for a long time.

The metals that were discussed, arsenic, beryllium, cadmium, copper, lead, and zinc, are all probably present naturally in the soils. Their detections are mostly on the same order as the background samples. As for fate and transport, beryllium can be expected to sorb to solid particles, basically immobilized. Arsenic and zinc may or may not be mobile. They both have forms that are soluble and can therefore move with groundwater. They are likely sorbed for the most part, and can probably be considered immobile. However, they may be transformed chemically or biologically to a soluble, mobile species. If so, they will travel with the groundwater toward Marlboro Brook. As stated above and elsewhere in this report, these metals probably exist naturally and are not related to site activity.

Lead, cadmium, and copper were also detected, and could be the result of on-site contamination. They (and other heavy metals) are sometimes associated with petroleum hydrocarbons, which were also detected on site. However, there were only a few hits of these metals, and they are most likely sorbed to solid particles.

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#### 6. HUMAN HEALTH RISK ASSESSMENT

General Volume I, Section 4 of the RI report describes the general risk assessment approach used and contains general information relevant to the human health risk assessments for both RI sites. This site-specific risk assessment for Site A12/P36/P37 includes additional site-specific information and presents a quantitative assessment of the potential human health risks from site-related contaminants.

This risk assessment is organized as follows:

- Section 6.1 provides an overview of Site A12/P36/P37 and describes the conceptual site model;
- Section 6.2 summarizes the chemicals detected at the site and identifies COPCs;
- Section 6.3 assesses the potential exposure of receptors to COPCs.
   Potential exposure pathways are reviewed and exposure estimates derived, taking into account the site setting and other site characteristics;
- Section 6.4 refers to the toxicity section presented in Section 4.3 in Volume I, which reviews toxicity assessment methodologies and presents brief toxicological summaries and quantitative indices of toxicity for COPCs; and
- Section 6.5 integrates the exposure estimates from Section 6.3 with toxicity indices from General Volume I, Section 4.3 to obtain quantitative risk estimates. Significant risks associated with the site are identified, along with the pathways and chemicals giving rise to these risks.

Figures and tables cited in the text are collected at the end of Section 6.

#### 6.1 INTRODUCTION

# 6.1.1 Overview

Site A12/P36/P37 is located in the southeast corner of the southern section of the Annex. Buildings T104 and T106 on Sites P36 and P37, respectively, were constructed in 1958 by Raytheon, originally to fulfill contracts with the USAF. Building T104 was built with its own septic system and leach field on the south side. Based on contract information, Building T104 was apparently used by Raytheon through the 1960s for research and

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development of missile guidance and radar systems, and for the manufacture of electronic equipment. Building T106, which is located approximately 300 feet east of Building T104, was used for assembly of electronic equipment during this time. During the 1970s, the buildings were used by Natick Laboratories Air Drop Engineering Laboratory for equipment development. The buildings were not used after 1980.

In 1983, Fort Devens began using the area just east of Building T104 (Site A12) for temporary storage of transformers prior to their removal from the Annex. In July 1985, personnel from Fort Devens discovered that a transformer, damaged by bullets, had leaked approximately 100 to 200 gallons of transformer oil to the ground. The fluid remaining in the transformer and all visibly contaminated soil in the release area were removed shortly thereafter, and additional soils were removed later in 1985 and 1986; analytical results from sampling conducted after the removals indicated that PCBs were present at concentrations less that 4 ppm. In 1988, two underground fuel oil storage tanks were removed from the site, a 10,000-gallon tank attached to Building T104 and a 1,000-gallon tank attached to Building T106. The smaller tank, which was in poor condition, had apparently leaked oil to the surrounding soil. Fuel-contaminated soil was removed, and the tank excavations were backfilled with clean soil. As a result of these known releases and past site activities, soils are contaminated with metals, PCBs, pesticides, and petroleum hydrocarbons.

Site A12/P36/P37 is no longer active. Although unauthorized personnel and visitors are prohibited from entering the Annex, trespassing is known to occur. Trespassers have been observed near the site, and there is other evidence of frequent trespassing such as trash, graffiti, and damage to the buildings. The nearest residences are located just outside the Annex boundary approximately 1,000 feet east of the site. When the Annex is released by the Army, this area could eventually be developed for future residential use.

Detailed descriptions of the site and the nature and extent of contamination are provided in previous sections of this report.

#### **6.1.2** Conceptual Site Model

A conceptual site model for A12/P36/P37 is presented on Figure 6-1. As shown on the figure, there are two main exposure pathways under both existing and possible future site conditions.

- Direct contact (dermal contact and incidental ingestion) with contaminated surface soils;
- Direct contact with contaminated sediment and surface water in Marlboro Brook, north of the site.

Potential receptors under current site conditions include workers who patrol the Annex and unauthorized site visitors, possibly trespassers from nearby residential areas. Within the Annex, the brook is not used for fishing or other recreational activities; therefore, contact with sediment and surface water contaminants is expected to be infrequent, relative to soils. Because the chemical concentrations detected in surface water were much lower than

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the levels found in sediment, and because surface water and sediment exposures would occur concurrently, potential human exposures through surface water contact are regarded as minor compared to sediment exposures. Direct contact with contaminants in subsurface soil and groundwater cannot occur under current conditions, however, some contaminants might eventually migrate in groundwater to the brook.

If the site were converted to residential use following installation closure, the existing soil, sediment, and surface water pathways would also apply to future residents. If residential construction involved soil excavation, which might bring subsurface soil contaminants to the surface, future site residents could potentially be exposed to both subsurface and surface soil contamination.

Groundwater near the site is not currently used as a water supply source nor is it expected to be used for that purpose in the future because of the relatively low yield of the aquifers and the availability of existing public water supplies. However, if future residents installed private wells on or downgradient of the site, they could potentially be exposed to additional contamination through domestic use of the groundwater.

# 6.2 IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN

#### 6.2.1 Data Collection

The RI investigative activities at Site A12/P36/P37 are described in Section 2. Environmental samples collected for chemical analyses included: two rounds of groundwater samples from six monitoring wells, 18 surface soil samples, subsurface soil samples from 11 locations, and sediment and surface water samples from three locations downgradient of the site. The analytical results for the RI samples are tabulated in Section 5.

# 6.2.2 Summary of Analytical Results and Chemicals of Potential Concern (COPCs)

The chemicals identified in the various environmental media sampled for the RI at Site A12/P36/P37 are summarized in Tables 6-1 through 6-5 as follows:

- Surface soil (see Table 6-1);
- Subsurface soil (see Table 6-2);
- Sediment (see Table 6-3);
- Surface water (see Table 6-4);
- Groundwater unfiltered (see Table 6-5); and
- Groundwater filtered (see Table 6-6).

The tables present the frequency of detection and the range of concentrations detected for each chemical identified. For metals and pesticides, which were measured in local

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background samples, the tables also list the local background screening concentrations (see Appendix J) and the frequency with which concentrations exceeding background were detected.

As explained in the general approach, all other chemicals detected in environmental media at the site were included as COPCs, unless they were attributed to laboratory or sampling contamination. Generally, metals and pesticides that were detected at concentrations exceeding background screening criteria were also included as COPCs; however, a few that exceeded the criteria only slightly and infrequently were omitted. These are discussed below.

Table 6-7 summarizes the COPCs identified in all environmental media sampled at Site A12/P36/P37.

#### 6.2.2.1 Soil (Tables 6-1 and 6-2)

Soil samples were collected from areas of suspected contamination adjacent to the buildings in the PCB spill area and in the leach field South of Building T104. Table 6-1 summarizes data for surface soil samples, and Table 6-2 summarizes data for subsurface soil samples. The maximum concentrations of all metals detected in site surface soils, except thallium, exceed local soil background values. Metals concentrations found in subsurface soil samples are generally similar or lower than surface soil concentrations. The highest metal concentrations were detected around the perimeter of Building T406.

PCBs and pesticides that were detected in a number of surface soil samples at concentrations exceeding background levels were also selected as COPCs; again, the highest concentrations were found near Building T104. Other soil COPCs include semivolatile organic compounds (phthalates and several PAHs that were detected at low levels in one surface soil sample) and petroleum hydrocarbons. Subsurface soils were found to be less contaminated; low levels of the PCB Aroclor 1260, phthalates, and total petroleum hydrocarbons (TPHCs) were detected.

#### **6.2.2.2** Sediment (Table 6-3)

Table 6-3 summarizes data for three sediment samples collected from Marlboro Brook, which receives groundwater discharge and surface drainage from the site.

The maximum detected concentrations of most metals are elevated in comparison to the local stream sediment background values; therefore, they were identified as COPCs. Generally, the highest metals concentrations in sediments were found at location E3-P37-D03, the location farthest from the site. The elevated metals concentrations found may have been due in part to the high organic carbon content of that sample. Pesticides were also detected in sediment at concentrations exceeding their respective local background levels, most at location E3-P37-D03. Other sediment COPCs include PAHs and TPHCs, which were detected in the same sample, and toluene.

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# 6.2.2.3 Surface Water (Table 6-4)

Table 6-4 summarizes surface water data and compares the metal concentrations detected with local stream surface water background values. The following COPCs were detected in at least one surface water sample at concentrations exceeding local background values for surface water: aluminum, arsenic, barium, chromium, cobalt, iron, lead, manganese, nickel, vanadium, and zinc. Almost all of these chemicals were also identified as COPCs in sediment. Bis(2-ethylhexyl)phthalate, which was detected in two surface water samples, is also a COPC.

# **6.2.2.4** Groundwater (Tables 6-5 and 6-6)

The analytical results for unfiltered groundwater samples collected by E & E for the RI are summarized in Table 6-5. Two rounds of samples were collected from five wells Background values used for screening were the maximum concentrations found in the upgradient well, E3-P36-M01. The maximum concentrations of arsenic, lead, zinc, and TPHCs detected in unfiltered groundwater samples from site monitoring wells exceed the concentrations found in the background well; therefore, they have been selected as COPCs. Although bis(2-ethylhexyl)phthalate was detected in groundwater, the levels were not elevated in comparison with the background sample data. No volatile organic chemicals were detected in site groundwater.

The metals data for filtered groundwater samples collected from the same site monitoring wells are summarized in Table 6-6. The maximum detected concentrations of most metals were substantially lower in filtered groundwater than in unfiltered groundwater samples. Lead, which appears to be slightly elevated in unfiltered groundwater, was not detected at all in the filtered groundwater samples. Direct comparison of the data from each filtered sample to the data from the corresponding unfiltered sample confirms that a substantial portion of the high concentrations of some metals detected in unfiltered samples is not dissolved in the groundwater, but is associated with suspended sediment.

Metals associated with suspended soil minerals are generally not mobile in groundwater and would not pose a health risk unless the water from these monitoring wells was used directly as a drinking water source. However, drinking water would not contain the high levels of sediments that have been found in the monitoring wells because drinking water supply wells are usually developed until suspended sediments are virtually eliminated. Nevertheless, EPA Region 1 has directed that the selection of groundwater COPCs and exposure estimates must be based on data from unfiltered groundwater. The use of unfiltered groundwater data overestimates the concentrations of metals that would be present in drinking water and most likely any realistic potential human health risks. Therefore, for comparison, alternate exposure and risk estimates based on the filtered groundwater data also are presented in this risk assessment.

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#### 6.3 EXPOSURE ASSESSMENT

This section includes only site-specific information pertinent to the assessment of potential human exposures to chemical contaminants at Site A12/P36/P37. General descriptions of the exposure assessment process and the exposure setting at the Annex can be found in General Volume I, Section 4.4.

# 6.3.1 Characterization of the Exposure Setting

#### 6.3.1.1 Physical Setting

Site A12/P36/P37 is located on the south side of Marlborough Road in the southern section of the Annex, approximately 1,000 feet from the eastern boundary. The site consists of Buildings T104 and T106 and the surrounding area, which is partially enclosed by a chain-link fence. Drums and other debris are scattered around the buildings. The roads and the parking area west of Building T104 are paved, and unpaved areas are moderately vegetated. The areas outside the fence are wooded. The ground slopes gently downward to the northeast. Groundwater and surface runoff both flow northeast to Marlboro Brook, which is 200 feet north of Building T106 at its closest point. The physical setting of the site is described in detail in Section 1 of this volume.

# **6.3.1.2** Potentially Exposed Populations

Site A12/P36/P37 is currently inactive, and the buildings have been closed off to prevent unauthorized entry. Authorized site visitors could include security personnel who may occasionally enter in the course of patrolling the Annex, and Fort Devens maintenance workers, who probably enter even less frequently. The most frequent visitors to the site are probably trespassers. Although unauthorized personnel are prohibited from entering the Annex, and the perimeter fence and road barriers discourage unauthorized entry, trespassers can enter fairly easily by passing around road barriers or through gaps in the fence. The nearest residences are located just outside the Annex boundary, approximately 1,000 feet east of the site. Adults and adolescents have been seen walking or biking near the site on Marlborough Road, and there is evidence of trespassing on the site, including graffiti and other damage to the buildings.

Once released by the Army, the Annex, including Site A12/P36/P37, could potentially be redeveloped for residential use. Groundwater near the site currently is not used and is unlikely to be used as a water supply source in the future because the aquifers near the site have relatively low yields and because there are existing public water supply systems in the nearby towns. However, if private wells were installed by future residents, they might be exposed to site-related contamination in the groundwater.

#### **6.3.2** Potential Exposure Pathways

A schematic depiction of the potential exposure pathways at Site A12/P36/P37 is presented on Figure 6-1, the conceptual site model.

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# 6.3.2.1 Sources and Receiving Media

As a result of past research and development activities and releases from transformers and fuel storage tanks, soils at Site A12/P36/P37 were apparently contaminated with metals, PCBs, pesticides, and other organic chemicals. Pesticide contamination may also be attributable in part to past widespread application of pesticides for insect control at the Annex.

# 6.3.2.2 Contaminant Fate and Transport

The soils beneath Site A12/P36/P37 are permeable and well-drained. As a result, precipitation tends to infiltrate carrying soluble contaminants to shallow groundwater that discharges to Marlboro Brook. Surface runoff from heavy precipitation flows northeast, potentially carrying contaminated surface soil particles to the brook.

Semivolatile organic chemicals, which were detected at low levels in site soil, have low to moderate solubilities. Some have a tendency to bind to organic carbon in soil. The more-soluble chemicals can leach to groundwater, then potentially migrate with groundwater to Marlboro Brook; however, many of these chemicals degrade over time.

PCBs, and pesticides have low water solubilities and a tendency to bind to organic carbon in soils and sediments; therefore, migration occurs primarily by transport of particles to which these chemicals are bound. PCBs and some pesticides, including DDD, DDE, and DDT, degrade very slowly and can accumulate in aquatic organisms.

Metals are generally insoluble and relatively immobile at the normal range of pH values; however, a metal's mobility also depends on the chemical forms present, and on soil characteristics such as clay and organic carbon content. Several metals were detected at higher concentrations in sediment than in site soil, possibly due to the higher organic carbon content of the sediment samples; this may be true in the cases of beryllium and zinc. Metals are persistent in the environment, and some, such as arsenic and selenium, can bioconcentrate in aquatic organisms.

#### **6.3.2.3** Complete Exposure Pathways

As shown on Figure 6-1, the following exposure pathways are potentially complete under existing site conditions:

- Direct contact (dermal contact and incidental ingestion) with contaminated surface soils by site visitors;
- Direct contact with nearby surface water and sediments by site visitors.

If the site was converted to residential use in the future, future site residents could potentially be exposed to soil, sediment, and surface water contaminants by the same pathways as current site visitors; however, they might also be exposed to soil contamination currently in the subsurface because excavation for construction could bring subsurface soils to

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the surface. Use of site groundwater by future residents is unlikely because there are existing public water supply systems in the surrounding communities. However, if future residents used on-site wells for their domestic water supply, they could potentially be exposed to additional contamination in groundwater through:

- Ingestion of drinking water; and
- Dermal contact while bathing or showering.

Table 6-8 summarizes potentially complete exposure pathways and receptors. The pathways and receptors selected for quantitative evaluation are identified, along with the reasons for selection or exclusion of each of the pathways.

Most of the pathways described above were quantitatively evaluated for the receptor group with the greatest expected exposure. Because the COPC concentrations detected in surface water were much lower than those found in sediment, risks from potential surface water exposures are likely to be minimal compared to potential sediment exposures; therefore, surface water exposures were not quantitatively assessed.

For potential future groundwater use, only drinking water ingestion was evaluated quantitatively. EPA Region I currently does not recommend the quantitation of dermal contact with groundwater during domestic use; because most of the groundwater COPCs are metals, which are minimally absorbed through the skin, this exposure route is not likely to be significant.

# 6.3.3 Quantification of Exposure

This section describes how quantitative exposure estimates were obtained. The first part describes how exposure point concentrations were selected or derived. The second part presents the exposure estimate calculations for each receptor and each route of exposure and explains the rationale for selecting the exposure factors used in the calculations.

#### **6.3.3.1** Exposure Point Concentrations

The exposure media of concern at Site A12/P36/P37 are current surface soil, future surface soil, sediment, and groundwater. Exposure point concentrations in each medium were determined directly from measured concentrations in that medium, as described below. As explained in the risk assessment approach section, the maximum observed concentration and the average concentration were used to estimate exposure point concentrations for the reasonable maximum exposure (RME) and average exposure cases, respectively, in accordance with EPA Region I guidance (USEPA 1989c).

Exposure point concentrations for direct contact with surface soil were estimated from all surface soil data collected at Site A12/P36/P37; the soil concentrations used are listed in Table 6-9. Future site development for residential use could involve excavation of soil anywhere on the site, which could bring subsurface contaminants to the surface. Because all of the subsurface soil samples were from depths of 10 feet or less, the subsurface soil data

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were combined with the surface soil data to estimate the future surface soil contaminant concentrations. These are listed in Table 6-10.

Exposure point concentrations for sediment contact were estimated using the sediment data for the three locations downgradient of the site in Marlboro Brook. Sediment COPC exposure point concentrations are listed in Table 6-11.

Future groundwater exposures were evaluated using data from all site monitoring wells except the background well (E3-P36-M01). For metals in groundwater, exposure point concentrations were estimated separately for filtered and unfiltered groundwater; two rounds of samples were collected from each of the wells. For the RME case, the exposure point concentration of each COPC was the maximum concentration detected in any well over all sampling rounds. For the average case, the average COPC concentration found in the wells was used. To calculate the overall well average, multiple round averages were first calculated for each well, then the average well concentrations were averaged together. Organic chemicals detected in unfiltered groundwater samples were assumed to be dissolved and, therefore, also present in filtered groundwater. Tables 6-12 and 6-13 present the exposure point concentration estimates for unfiltered groundwater and filtered groundwater, respectively.

# 6.3.3.2 Exposure Estimation

As explained previously, two exposure scenarios were selected for the quantitative risk assessment: a current site visitor scenario and a future residential scenario. The equations used to estimate the exposure for each route of exposure are provided in Tables 6-14 through 6-20. The exposure factor values used in the calculations are also provided, along with the rationale for their selection and a reference source. In accordance with EPA Region I Guidance (USEPA 1989c), the same exposure factor values were used for both the RME and average case.

For Pathway 1A, all of the exposure factors will be described and values discussed in the text. For subsequent pathways, the discussion will focus on the exposure factors and values that have not already been explained.

#### Scenario 1: Exposures of Site Visitors

Site visitors include two main groups: Fort Devens security and maintenance workers who might occasionally visit the site in the course of their duties, and Annex trespassers, who may include both adults and adolescents from nearby residential areas. Most receptors would be expected to visit the site infrequently and briefly, having minimal contact with contaminated soil and sediment. The receptor group with the greatest potential exposures is trespassers who might intentionally enter and spend longer periods, perhaps hours, on the site. These are most likely to be adolescents from nearby residential areas exploring around the buildings or playing in the area.

Because the site is quite close to the Annex boundary and off-site residences, frequent trespassing is possible. Even so, it is unlikely that a trespasser would visit Site A12/P36/P37

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(or any other area) exclusively. Exposure to soil and sediment were evaluated separately using most of the same exposure factors except for exposure frequency; sediment exposures were assumed to occur less frequently than soil exposures. The exposure factors selected for visitors are thought to be credible but conservative.

# Pathways 1A and 1C—Ingestion of Chemicals in Surface Soil and Sediment (Table 6-14)

The contaminant concentrations in soil (CS) are the average and maximum concentrations detected. The soil ingestion rate is the amount of soil or sediment that an individual might ingest through hand-to-mouth contact; the value used is EPA's standard default assumption for receptors more than 6 years old (USEPA 1991a). The relative absorption factor (RAF) accounts for the differing bioavailability between the contaminant in soil and in the administered medium (e.g., food, water) that is the basis for the toxicological index; default values are taken from EPA Region I Guidance (USEPA 1989c). The RAF values used are summarized in Table 6-21.

The fraction ingested (FI) is the fraction of soil or sediment that comes from the contaminated area of interest; this value was assumed to be 0.5, with the remainder coming from other areas. The exposure frequency is assumed to be 100 days per year for soil (approximately every day of the summer) and 30 days for sediment. The exposure duration (ED), assuming adolescence lasts from ages 6 though 17, is 12 years.

The body weight (BW) used is the average reported for the age group (USEPA 1989h). The averaging time (AT) is the period over which the estimated exposure is averaged. For noncarcinogens, the averaging time is equal to the exposure duration, but for carcinogens it is taken as the standard life expectancy of 70 years because the carcinogenic potency slope factors (described in Volume I, Section 5.3.3.2) are based on lifetime exposure.

#### Pathways 1B and 1D—Dermal Contact with Surface Soil and Sediment (Table 6-15)

The absorption factor (ABS) is the fraction of chemical absorbed from soil or sediment through the skin. Currently absorption values are available for only two of the COPCs identified in soil at A12/P36/P37, cadmium and PCBs; therefore, those are the only chemicals that will be evaluated for the dermal route. The values shown are taken from EPA Dermal Exposure Assessment Guidance (USEPA 1992d). The skin area (SA), which is the area of exposed skin which might contact soil, is estimated to be 25 percent of an individual's total body surface area based on EPA's recommendations in its dermal guidance (USEPA 1992d) and is approximately equivalent to the combined surface areas of the head, the hands, one-half of the arms, and one-half of the legs. The adherence factor is an estimate of the amount of soil that might cling to the skin and serve as a source of exposure. The fraction of contacted soil and sediment from the contaminated area of interest (FC), like the fraction ingested, is assumed to be half of the amount contacted.

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# Scenario 2: Future Residential Exposure

Two groups of receptors (adults exposed for 30 years and children 6 years old and under) were considered for the soil and groundwater exposure pathways evaluated for residential exposures. The child receptor was used to evaluate potential risks from subchronic exposures of this potentially sensitive age group, which might otherwise be "diluted" and be overlooked if only a 30-year exposure was considered.

Receptors potentially exposed to stream sediment were assumed to be adolescents from 6 through 17 years old. Adolescent site residents of this age are more likely than adults or small children to wander from their homes and to play in nearby streams, particularly during the warmer months of the year.

# Pathway 2A—Ingestion of Chemicals in Surface Soil (Table 6-16)

The ingestion rates (IR) used are EPA's standard default soil ingestion values for receptors more than 6 years old and receptors less than 6 years old (USEPA 1991a); the default values account for ingestion of both outdoor soil and indoor dust. The fraction ingested (FI) is assumed to be 1.0 because some adults and small children would be expected to spend all or most of their time at home. The exposure frequency (EF) is also an EPA default value, which represents year-round exposure allowing for two weeks of the year spent away from the area. Although snow cover may prevent contact with outdoor soil for part of the year, contact with contamination in indoor dust, which could approach levels in outdoor soil, occurs year-round. The exposure duration (ED) for young children is 6 years; for adults, ED is assumed to be 30 years, the 90th percentile length of time living at one residence. The body weights (BW) for adults and children are EPA standard default values (USEPA 1991a).

# Pathway 2B—Dermal Contact with Surface Soil (Table 6-17)

The skin area (SA) used for adults is estimated to be 25 percent of an individual's total body surface area, based on EPA's recommendations in its Dermal Guidance (USEPA 1992d), and is approximately equivalent to the combined surface areas of the head, the hands, one-half of the arms, and one-half of the legs. For children, the same body parts are assumed to be exposed; the SA value is 40 percent of the total skin surface area reported for children 2 to 6 years old (USEPA 1992d).

# Pathway 2C-Ingestion of Chemicals in Sediment (Table 6-18)

The receptor most likely to have contact with sediment is assumed to be an adolescent from age 6 through 17. Except for the exposure frequency (EF), the exposure factors used are identical to those assumed for adolescent site visitors under current conditions. The EF for the future resident's exposure to sediment is assumed to be 100 days per year, approximately equivalent to every day of the summer. This frequency is reasonable for an adolescent who lives on the site, close to the stream. The fraction ingested (FI) from contaminated sediment is assumed to be one-half of the total ingested soil and sediment; the remainder could come from other areas, including on-site soil.

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# Pathway 2D-Dermal Contact with Chemicals in Sediment (Table 6-19)

As with the sediment ingestion route above, the exposure factors are identical to those used for current adolescent trespassers except for the EF, which is assumed to be 100 days per year.

# Pathway 2E-Ingestion of Chemicals in Drinking Water (Table 6-20)

The contaminant concentrations in groundwater (CW) are the average and maximum concentrations detected (see Section 6.3.3.1 above). The ingestion rates (IR) for adults and children are default values recommended for daily tap water consumption (USEPA 1989h).

#### 6.4 TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to compile toxicity data for the COPCs at the site and to provide an estimate of the relationship between the extent of exposure to a contaminant and the likelihood and/or severity of adverse health effects. Because many of the COPCs identified at Site A12/P36/P37 were also identified at Site P11/P13, a single toxicity assessment was prepared for both sites. The toxicity assessment, which also describes toxicity assessment methodologies, is presented in Section 4.3 of Volume I.

#### 6.5 RISK CHARACTERIZATION

This section presents the quantitative estimates of potential human health risks posed by site-related contaminants at Site A12/P36/P37 for RME and average exposure cases, and compares those estimates with risk levels deemed acceptable by EPA. The RME cases use the maximum observed COPC concentrations to estimate exposures; the average cases use average concentrations. A general description of the methods used to calculate cancer risks and noncancer hazard indices are described in General Volume I, Section 4.5 of this report. Risk assessment uncertainties are discussed in General Volume I, Section 4.6.

#### 6.5.1 Risk Estimates

Detailed tables containing estimates of exposures and associated risks for the scenarios described in Section 6.3.3 are presented in Appendix O. Subchronic RfDs were used to calculate hazard indices (HIs) for receptors with exposure durations less than seven years (children), whereas chronic RfDs were used for those with EDs greater than seven years. A directory has been included in the appendix to assist the reader in locating the exposure and risk estimates for specific exposure pathways, receptors, etc. (see Appendix O). Tables 6-22 and 6-23 summarize the total cancer risks and noncancer hazard indices from the tables in Appendix O. These tables also show which exposure pathways are most responsible for the estimated risks.

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# 6.5.2 Magnitude and Sources of Risks Posed by Site Contaminants

Under the current EPA Superfund policy (USEPA 1992b), acceptable exposures to carcinogens are those that represent an excess upper bound lifetime cancer risk of between 10⁻⁴ to 10⁻⁶. For noncarcinogenic effects, acceptable exposures levels are those with an HI of 1.0 or less.

#### 6.5.2.1 Current Risks

The estimated potential cancer risks for RMEs to contaminants at Site A12/P36/P37 (see Table 8-18) are 1.1 x 10⁻⁵ for the adolescent site trespasser's exposure to soil and 1.1 x 10⁻⁶ for the adolescent site trespasser's exposure to sediment. These are within the 10⁻⁴ to 10⁻⁶ range. The estimated cancer risks associated with soil are due mainly to dermal absorption and ingestion of PCBs (86 percent) and ingestion of arsenic (12 percent), whereas those associated with sediment are primarily due to arsenic ingestion (93 percent). The RME case assumes that all of a receptor's exposure is to the maximum contaminant concentrations observed at the site. For soil, the cancer risks associated with average exposure generally are approximately one-fifth of the RME risks. Cancer risks associated with average exposures to sediments are less than one-half of the RME risks.

Both the soil and sediment exposure pathways could reasonably apply to the same site trespassers. Therefore, the estimated risks from soil and sediment contact should be summed to estimate the total receptor risk. Combining the RME risk estimates from these two pathways results in total estimated cancer risks of  $1.2 \times 10^{-5}$ , still within the  $10^{-4}$  to  $10^{-6}$  range.

HIs for potential reasonable maximum exposures to noncarcinogenic COPCs in soil and sediment are below EPA's benchmark value of 1.0. The total HIs of trespassers from soil and sediment contact pathways together are also below 1.0, indicating that the occurrence of adverse noncarcinogenic health effects as a result of exposure to site-related chemicals is highly unlikely under existing site conditions.

#### 6.5.2.2 Future Risks

Under a possible future residential scenario, the estimated potential cancer risks from RMEs to site soil contamination are 1.6 x 10⁻⁴ for adult residents and 1.2 x 10⁻⁴ for children, both above the 10⁻⁴ to 10⁻⁶ range deemed acceptable by EPA. The estimated cancer risks for the average exposure case are lower by approximately an order of magnitude. The bulk of the estimated cancer risk is due to dermal absorption and ingestion of PCBs (89 percent) and to ingestion of arsenic (9 percent) and beryllium (1 percent). Noncancer HIs associated with residential RMEs to soil contaminants total 0.77 for adults and 3.7 for children; the child's HI is above the acceptable HI of 1.0. For children's exposures to site soils, PCB-1254 is the only COPC with a HI greater than 1.0; the estimated noncancer HI associated with dermal absorption and ingestion of PCB-1254 is 1.6.

Potential cancer risks to adolescent site residents from exposure to sediments are estimated to be  $3.8 \times 10^{-6}$  for the RME case and  $1.7 \times 10^{-6}$  for the average exposure case.

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Most of the estimated cancer risk (93 percent) is due to ingestion of arsenic. Noncancer HIs associated with sediment exposures were well below 1.0, indicating that sediment contaminants are unlikely to cause adverse health effects.

Estimated potential cancer risks from consumption of unfiltered groundwater under the RME case are  $2.1 \times 10^{-3}$  for adults and  $9.9 \times 10^{-4}$  for children, above the  $10^{-4}$  to  $10^{-6}$  range. Average case risk estimates were approximately one quarter as great. All of the estimated cancer risk is due to ingestion of arsenic. However, the higher concentrations of arsenic detected in unfiltered groundwater are associated with suspended sediments at levels that would probably not be present in groundwater actually used as drinking water (see Section 6.2.2.4). When metals data from filtered groundwater samples are used to remove the effects of suspended sediment, estimated RME cancer risks drop by a factor of 50 to 4.5 x  $10^{-5}$  and  $2.1 \times 10^{-5}$  for adults and children, respectively.

Total HIs for noncarcinogenic effects from consumption of groundwater based on data from unfiltered groundwater samples are 9.2 for adults and 21 for children under the RME case; HIs are approximately one-quarter as great for the average exposure case. The RME total for children is mostly due to arsenic (HI=21). When the risks are recalculated using metals data from filtered groundwater samples, the total HIs for the RME case drop to 0.29 for adults and 0.34 for children, indicating that noncarcinogenic effects are unlikely.

Because future residents could potentially be exposed to contaminants in both soil and groundwater, the risks from these media should be summed for these receptors. Combining the estimated RME cancer risks for adult residents gives a total cancer risk of approximately  $2.3 \times 10^{-3}$  based on unfiltered groundwater data, or  $6.6 \times 10^{-4}$  based on filtered groundwater data.

#### 6.5.3 Risks from Lead

Lead, which has no EPA-approved RfD or SF, was not included in the quantitative risk estimates. The maximum observed lead concentration at Site A12/P36/P37 was 260 mg/kg detected in surface soil. That concentration is well below EPA's recommended screening level of 400 ppm for lead in residential soil, suggesting that serious human health effects from exposure to lead in site soil and sediment are unlikely.

Lead was also detected in unfiltered groundwater from site monitoring wells. Lead concentrations exceeding EPA's drinking water action level of 15  $\mu$ g/L were found in two of the five downgradient wells, as well as the background well, and the maximum observed concentration was 29.8  $\mu$ g/L. However, the elevated lead concentrations appear to be associated with high levels of suspended sediments in the unfiltered samples, levels that would not be present in a well developed for drinking water use. Lead concentrations in all filtered groundwater samples were less than 5  $\mu$ g/L, confirming that the higher lead concentrations in unfiltered samples were due to suspended sediments, and indicating that lead in site groundwater does not pose a significant hazard to human health.

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# 6.5.4 Perspective on Arsenic Exposure and Risks

A major portion of the estimated risks associated with all exposure pathways evaluated at Site A12/P36/P37 are due to potential exposure to arsenic, which was detected at concentrations greater than background levels in soil, sediment, and groundwater. Nevertheless, the arsenic levels found in these media were only modestly elevated. Although all of the arsenic concentrations detected in site sediment exceed the local stream sediment background value (2.03  $\mu$ g/g), the maximum detected concentration, 37.4  $\mu$ g/g, which is associated with an estimated cancer risk of 3.5 x 10⁻⁶, is less than 4 times the local soil background level (10  $\mu$ g/g). The maximum arsenic concentration detected in soil, 14  $\mu$ g/g, which is associated with an estimated cancer risk of 1.5 x 10⁻⁵, is only 40 percent greater than the local soil background value. Similarly, the maximum arsenic concentration detected in filtered site groundwater, 2.14  $\mu$ g/L, which is associated with a cancer risk of 4.5 x 10⁻⁵ if present in drinking water, is less than twice the arsenic concentration detected in the background well and well below the current drinking water standard for arsenic. Because arsenic is naturally present in the environment, humans are exposed to arsenic in food, air, and water on a daily basis. Therefore, to put the potential site-related exposures and risks in perspective, it is important to be aware of the routine nonsite-related exposures to arsenic and the risks that could be associated with those exposures. Table 6-24 compares estimated risks from routine intake of arsenic to risks associated with potential exposures to arsenic in site soil, sediment, and groundwater.

The general population of the United States is estimated to be exposed to 25 to 50 µg of arsenic per day, primarily in food and drinking water (ATSDR 1993; WHO 1981). For a 70-kg adult, these intake rates correspond to estimated cancer risks of 6 x  $10^{-4}$  to 1 x  $10^{-3}$ and an estimated hazard index of 1.2 to 2.4 for noncarcinogenic effects. The Federal MCL for arsenic in drinking water is 50 µg/L. Using EPA's standard default drinking water EFs, the MCL concentration would correspond to an estimated cancer risk of 2.5 x 10⁻³ and an estimated hazard index of 4.8.

#### 6.5.5 Nature of Potential Adverse Health Effects

The site contaminants estimated to pose potential excess lifetime cancer risks greater than 10⁻⁶ include arsenic, beryllium, and PCBs. Arsenic is classified as a Group A, human carcinogen. Oral exposure to arsenic is known to cause skin cancer, and there is mounting evidence that ingestion of arsenic may also cause liver, kidney, bladder, or lung cancer. Beryllium and PCBs are classified as Group B2, probable human carcinogens, based on carcinogenicity in animals. Beryllium has caused various types of tumors in exposed animals. Oral exposures to PCBs are associated with liver cancer.

Site contaminants that pose potentially significant noncarcinogenic adverse health effects via ingestion or dermal routes include arsenic, and PCBs. Overexposure to arsenic can cause damage to the kidneys and blood, weight changes, and possible keratosis and hyperpigmentation of the skin in humans. In animals, PCBs have caused liver damage, skin irritations, low birth weights and other reproductive effects, immunosuppression, and death; however, the only significant adverse health effects reported in PCB-exposed workers are skin irritations and liver effects.

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# 6.5.6 Major Factors Driving Estimated Site Risks

The major factors driving estimated site risks are:

- The presence of PCBs and arsenic in site soils and potential exposures by site trespassers and future site residents; and
- The presence of elevated concentrations of metals (primarily arsenic) in the groundwater coupled with the possible future use of groundwater as a drinking water source.

Exposures to soil contaminants are either currently occurring or could reasonably be expected under current land-use conditions; however, the conservative (health protective) exposure assumptions used may overestimate actual exposures.

Groundwater near the site is not a current, nor a likely future, water supply source because of the low yield of the aquifer and the availability of an existing public water supply system. Therefore, the probability of exposure to site contaminants in groundwater is extremely small.

Figure 6-1 CONCEPTUAL SITE MODEL FOR SITE A12/P36/P37

Table 6-1 SUMMARY OF SURFICIAL SOIL ANALYTICAL RESULTS SITE A12/P36/P37  $(\mu g/g)$ 

		Rai	nge		
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background
Inorganics					
Aluminum ^c	18/18	5,390	14,000	10,400	7/18
Antimony ^c	3/18	1.01	5.74	<0.5 ^b	3/18
Arsenic ^c	18/18	5.52	14.0	10	1/18
Barium ^c	18/18	9.62	200 ^a	25.1	. 11/18
Beryllium ^c	18/18	0.147	0.581	0.446	7/18
Cadmium ^c	5/18	1.38	15.3	<0.5 ^b	5/18
Calcium ^c	13/18	342	4,710	1,170	2/18
Chromium ^c	18/18	9.34	73.3	14.2	13/18
Cobalt ^c	18/18	4.84	21.1 ^a	6.1	12/18
Copper ^c	18/18	6.82	94.35 ^a	10.7	12/18
Iron ^c	18/18	7,480	66,000	12,300	10/18
Lead ^c	18/18	7.60	260 ^a	150	1/18
Magnesium ^c	. 18/18	1,540	3,440	2,310	11/18
Manganese ^c	18/18	105	346.5 ^a	95.8	18/18
Nickel ^c	18/18	9.02	43.6ª	10.7	15/18
Potassium ^c	18/18	433	2,140	617	12/18
Sodium ^c	4/18	170	538.5 ^a	200	2/18
Thallium	1/18	0.149	0.149	<0.5 ^b	0/18
Vanadium ^c	18/18	10.6	36.3	33.0	1/18
Zinc ^c	18/18	23.1	2,300	44.6	17/18

Table 6-1

# SUMMARY OF SURFICIAL SOIL ANALYTICAL RESULTS SITE A12/P36/P37

 $(\mu g/g)$ 

		Ra	nge			
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background	
Pesticides/PCBs						
α-Chlordane ^c	1/26	0.018	0.018	0.004	1/26	
γ-Chlordane ^c	2/26	0.002	0.0545	0.005	1/26	
p,p'-DDT ^c	17/26	0.005	0.940	0.233	3/26	
p,p'-DDD	7/26	0.004	0.052	0.063	0/26	
p,p'-DDE	15/26	0.004	0.094	0.139	0/26	
Endosulfan, B ^c	7/26	0.002	0.111	0.004	6/26	
Methoxychlor	1/26	0.018	0.018	0.023	0/26	
PCB 1254 ^c	1/26	2.00	2.00	<0.02 ^b	1/26	
PCB 1260 ^c	15/26	0.090	6.30	<0.02 ^b	15/26	
Semivolatile Organics						
Bis(2-ethylhexyl)phthalate ^c	4/18	0.046	1.30	ı	ı	
Benzo(b)fluoranthene ^c	1/18	0.082	0.082	1	-	
Butylbenzylphthalate ^c	1/18	0.130	0.600	1	1	
Fluoranthene ^c	1/18	0.081	0.081		_	
Pyrene ^C	1/18	0.090	0.090	_	_	
Other Organics	Other Organics					
Total Petroleum Hydrocarbons ^c	20/24	27.5	1,800	-	-	

a Average of duplicate samples.b Contract reporting limit.

Key:

- = Not analyzed/not applicable.

^C Selected as a COPC.

Table 6-2 SUMMARY OF SUBSURFACE SOIL ANALYTICAL RESULTS SITE A12/P36/P37  $(\mu g/g)$ 

		Ra	Range		
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background
Inorganics					
Aluminum ^c	15/15	3,700	11,000	10,400	1/15
Antimony ^c	2/15	0.310	2.02	<0.5 ^b	1/15
Arsenic	15/15	2.84	7.20	10	0/15
Barium ^c	15/15	16.0	47.5	25.1	7/15
Beryllium ^c	12/15	0.189	0.473	0.446	2/15
Cadmium ^c	8/15	0.336	64.3	<0.5 ^b	2/15
Calcium ^c	14/15	241	1,350	1,170	2/15
Chromium ^c	15/15	8.14	19.2	14.2	5/15
Cobalt ^c	15/15	3.82	7.77	6.1	5/15
Copper ^c	15/15	5.21	17.8	10.7	7/15
Iron ^c	15/15	6,500	15,000	12,300	3/15
Lead	4/15	1.79	23.0	150	0/15
Magnesium ^c	15/15	1,260	3,650	2,310	3/15
Manganese ^c	15/15	67.4	163	95.8	9/15
Mercury	2/15	0.085	0.094	0.318	0/15
Nickel ^c	15/15	6.08	19.8 ^a	10.7	5/15
Potassium ^c	15/15	693	2,640	617	15/15
Selenium	1/15	0.192	0.192	0.571	0/15
Thallium	4/15	0.148	0.233	<0.5 ^b	0/15
Vanadium	. 15/15	8.52	24.6	33.0	0/15
Zinc ^c	14/15	13.2	150	44.6	3/15

Key at end of table.

Table 6-2

# SUMMARY OF SUBSURFACE SOIL ANALYTICAL RESULTS SITE A12/P36/P37

 $(\mu g/g)$ 

400						
		Range				
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background	
Pesticides/PCBs						
PCB 1260 ^c	2/23	0.116	0.190	<0.02 ^b	2/23	
Semivolatile Organics						
Butylbenzyl phthalate ^c	1/15	0.130	0.130		-	
Di-n-octyl phthalate ^c	2/13	0.028	0.120	_	-	
Other Organics						
Total petroleum hydrocarbons ^c	10/15	10.7	27.6	-	_	

<sup>a Average of duplicate samples.
b Contract reporting limit.
c Selected as a COPC.</sup> 

# Key:

- = Not analyzed/not applicable.

		4.6.6			
		Range			
Analyte	Detection Frequency	Minimum	Maximum	Local Stream Sediment Background	Frequency of Exceedance of Background
Inorganics					
Aluminum	3/3	3,910	4,870	5,020	0/3
Antimony ^b	1/3	1.72	1.72	<0.5 ^a	1/3
Arsenic ^b	3/3	3.01	37.4	2.03	3/3
Barium ^b	3/3	17.1	72.9	23.9	1/3
Beryllium ^b	3/3	0.217	1.09	0.18	3/3
Cadmium ^b	1/3	2.50	2.50	<0.5 ^a	1/3
Calcium ^b	3/3	306	4,650	562	2/3
Chromiumb	3/3	5.91	10.1	9.66	1/3
Cobalt ^b	3/3	3.56	25.3	3.74	2/3
Copper ^b	3/3	4.25	15.4	6.33	2/3
Iron ^b	3/3	5,070	26,500	7,590	2/3
Lead ^b	3/3	3.22	39.2	4.48	2/3
Magnesium ^b	3/3	362	203,000	2,140	1/3
Manganeseb	3/3	115	1,680	70.5	3/3
Nickel ^b	3/3	6.50	20.7	5.92	3/3
Potassium	2/2	373	888	1,520	0/3
Selenium ^b	1/3	0.852	0.852	0.2	1/3
Thallium	1/1	0.093	0.093	0.195	0/1
Vanadium ^b	3/3	6.50	21.8	17	1/3
Zinc ^b	3/3	32.6	72.9	20.8	3/3
Pesticides		,		-	
alpha-BHC ^b	1/3	0.027	0.027	<0.003 ^a	1/3
gamma-Chlordane ^b	1/3	0.190	0.190	<0.008 ^a	1/3

Key at end of table.

Table 6-3 SUMMARY OF SEDIMENT ANALYTICAL RESULTS SITE P37

 $(\mu g/g)$ 

		Range			
Analyte	Detection Frequency	Minimum	Maximum	Local Stream Sediment Background	Frequency of Exceedance of Background
p,p'-DDE ^b	2/3	0.097	0.345	<0.002 ^a	2/3
Endosulfan, B ^b	1/3	0.001	0.001	<0.002a	1/3
Endrin ^b	1/3	0.024	0.024	<0.002a	1/3
Heptachlor epoxide ^b	1/3	0.114	0.114	<0.001 ^a	1/3
Semivolatile Organics					
Fluorantheneb	1/3	0.290	0.290	-	I
Pyrene ^b	1/3	0.310	0.310	I	_
Volatile Organics					
Toluene ^b	1/3	0.030	0.030	-	_
Other Organics					
Total petroleum hydrocarbons ^b	1/3	174	174	16.6	1/3

a Contract reporting limit.b Selected as a COPC.

# Key:

- = Not analyzed/not applicable.

Table 6-4 SUMMARY OF SURFACE WATER ANALYTICAL RESULTS SITE P37 ( $\mu$ g/L)

		Ra	nge			
Analyte	Detection Frequency	Minimum	Maximum	Local Background	Frequency of Exceedance of Background	
Inorganics						
Aluminumb	3/3	156	7,060	400	2/3	
Arsenic ^b	3/3	2.59	45.8	3.15	2/3	
Barium ^b	3/3	7.70	52.2	10.4	2/3	
Beryllium	1/1	1.39	. 1.39	<5ª	0/1	
Calcium	3/3	2,260	7,050	8,520	0/3	
Chromium ^b	1/3	8.52	8.52	3.16	0/3	
Cobalt ^b	2/3	7.51	10.2	4.79	2/3	
Copper	2/3	3.76	6.27	<10 ^a	0/3	
Iron ^b	3/3	903	14,000	4,810	2/3	
Lead ^b	2/3	11.4	23.2	10.3	2/3	
Magnesium	3/3	658	1,390	1,890	0/3	
Manganese ^b	3/3	124	1,700	156	2/3	
Nickel ^b	1/3	10.6	10.6	<10 ^a	1/3	
Potassium	3/3	319	1,060	2,060	0/3	
Sodium	3/3	2,880	4,700	14,000	0/3	
Vanadium ^b	2/3	6.05	9.51	4.72	2/3	
Zinc ^b	3/3	20.4	46.5	13.3	3/3	
Semivolatile Organics	Semivolatile Organics					
Bis(2-ethylhexyl)phthalateb	2/3	1.40	24.0	_	-	

^aContract reporting limit. b_{Selected} as a COPC.

Key:

^{— =} Not analyzed/not applicable.

Table 6-5 SUMMARY OF ANALYTICAL RESULTS FOR UNFILTERED GROUNDWATER SITE P36/P37 (μg/L)

		Range			<i>'</i>
Analyte	Detection Frequency	Minimum	Maximum	Local Background (E3-P36-M01)	Frequency of Exceedance of Background
Inorganics					
Aluminum	10/10	1,190	45,000	84,000	0/10
Antimony	4/10	1.85	2.26 ^a	<5.0 ^c	0/10
Arsenic ^b	10/10	1.84	100	35.2	2/10
Barium	10/10	15.6	232	561	0/10
Beryllium	7/10	0.349	2.09	3.96	0/10
Cadmium	2/10	1.93 ^a	2.70	3.34	0/10
Calcium	10/10	2,480	10,800	14,400	0/10
Chromium	9/10	7.08	67.2	208	0/10
Cobalt	9/10	3.65	47.6	65.8	0/10
Copper	10/10	5.90	108	182	0/10
Iron	10/10	1,390	62,000	86,000	0/10
Lead ^b	8/10	2.07	29.8	24.0	1/10
Magnesium	10/10	855	12,400	26,200	0/10
Manganese	10/10	79.8	1,200	1,200	0/10
Nickel	8/10	11.2ª	61.9	166	0/10
Potassium	7/10	1,860	9,170	22,000	0/10
Sodium	8/10	4,120	11,200	14,000	0/10
Vanadium	9/10	5.20	81.1	187	0/10
Zinc ^b	9/10	25.4	282	180	1/10
Semivolatile Organics					
Bis(2-ethylhexyl) phthalate	2/10	2.50	4.40	<10	0/10
Other Organics					
Total petroleum hydrocarbons ^b	2/10	1,290	1,930	266	2/10

a Average of duplicate samples.
 b Selected as a COPC.
 c Contract reporting limit.

Key:

ND = Not detected.

Table 6-6  $SUMMARY\ OF\ ANALYTICAL\ RESULTS\ FOR\ FILTERED\ GROUNDWATER$   $SITE\ P36/P37\ (\mu g/L)$ 

		Ra	nge		
Analyte	Detection Frequency	Minimum	Maximum	Local Background (E3-P36-M01)	Frequency of Exceedance of Background
Inorganics					
Aluminum	1/10	25.55	25.55	23.6	0/10
Arsenic	4/10	0.840	2.14	1.31	0/10
Barium	8/10	4.80	10.2	7.75	0/10
Calcium	10/10	2,015	6,980	6,400	1/10
Chromium	1/10	4 ^a	4 ^a	<10.0	0/10
Cobalt	1/10	2.2	2.2	<10.0	0/10
Copper	1/10	4.32	4.32	4.37	0/10
Magnesium	10/10	489.5	1,220	909	2/10
Manganese	8/10	20.1	224	124	2/10
Potassium	5/10	662	1,600	1,430	1/10
Sodium	7/10	3,330	8,890	12,300	0/10
Vanadium	2/7	3.58 ^a	4.73	<10.0	0/10
Zinc	1/10	71.9	71.9	22.4	2/10

a Detected in one of two duplicate samples.

Table 6-7

# CHEMICALS OF POTENTIAL CONCERN SITE A12/P36/P37

Chemical	Surface Soil	Subsurface Soil	Sediment	Surface Water	Groundwater
Metals					
Aluminum	х	х		Х	
Antimony	х	X	х		
Arsenic	х		х	х	Х
Barium	х	х	х	X	
Beryllium	X	х	Х		
Cadmium	х	х	х		
Calcium	X	х	Х		
Chromium	х	х	X	X	
Cobalt	х	х	х	X	
Copper	х	х	X		
Iron	X	Х	х	X	
Lead	х		Х	X	х
Magnesium	X	х	х		
Manganese	X	х	х	X	,
Nickel	х	х	х	X	
Potassium	х	х			
Selenium			х		
Sodium	Х				
Vanadium	Х		х	X	
Zinc	X	х	х	X	х
Pesticides/PCBs					
alpha-BHC			х		
alpha-Chlordane	х				
gamma-Chlordane	х		х		
p,p'-DDE			x		,
p,p'-DDT	х			, .	
Endosulfan, B	х		х		

Key at end of table.

Table 6-7

# CHEMICALS OF POTENTIAL CONCERN SITE A12/P36/P37

Chemical	Surface Soil	Subsurface Soil	Sediment	Surface Water	Groundwater
Endrin			х		
Heptachlor epoxide			х		
PCB 1254	X				
PCB 1260	X	х			
Semivolatile Organics			1		
Bis(2-ethylhexyl)phthalate	X			X	
Butylbenzylphthalate	X	Х			
Di-n-octylphthalate		Х			
Benzo(b)fluoranthene	X				
Fluoranthene	X		х		
Pyrene	X		X		
Volatile Organics					
Toluene			х		
Other Organics					
Total petroleum hydrocarbons	х	х	х		X

Note: Groundwater COPC selection is based on unfiltered groundwater data.

Key:

X = Selected as a COPC for the human health risk assessment.

Table 6-8								
PO	POTENTIAL HUMAN EXPOSURE PATHWAYS SITE A12/P36/P37							
Potentially Exposed Population Exposure Routes, Medium, and Exposure Points Pathway Selected for Exposure Points Evaluation Or Exclusion								
Current Land Use								
Site visitors (trespassers)	Dermal absorption and ingestion of COPCs in site soil	Yes	COPCs ^a have been found in site soil. Trespassing has occurred.					
	Dermal absorption and ingestion of COPCs in sediment	Yes	COPCs have been found in nearby stream sediment.					
	Dermal absorption and ingestion of COPCs in surface water	No	Surface water COPC levels are much lower than those detected in sediment. Potential exposures are minimal in comparison.					
Future Land Use								
Future site residents	Dermal absorption and ingestion of COPCs in site soil.	Yes	COPCs have been found in site soil.					
	Dermal absorption and ingestion of COPCs in sediment	Yes	COPCs have been found in nearby stream sediment.					
	Dermal absorption and ingestion of COPCs in surface water	No	Surface water COPC levels are much lower than those detected in sediment. Potential exposures are minimal in comparison.					
	Use of groundwater as residential drinking water	Yes	Future residents could install private wells on site or downgradient.					
	Dermal contact while bathing or showering.	No	EPA Region I currently does not recommend the quantitation of dermal					

a Chemicals of potential concern.

contact.

Table 6-9

# CURRENT SURFACE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37

 $(\mu g/g)$ 

Chemical	Average	Maximum
Metals		
Aluminum	9,330	14,000
Antimony	0.822	5.74
Arsenic	7.57	14.0
Barium	37.6	200
Beryllium	0.374	0.581
Cadmium	2.50	15.3
Calcium	824	4,710
Chromium ^a	20.0	73.3
Cobalt	8.42	21.1
Copper	23.8	91.4
Iron	18,500	66,000
Lead	42.9	260
Magnesium	2,340	3,440
Manganese	158	346
Nickel	15.3	43.6
Potassium	1,110	2,140
Sodium	153	538
Vanadium	23.0	36.3
Zinc	527	2,300
PCBs		
PCB-1254	0.110	2.00
PCB-1260	0.833	6.30
Pesticides		
alpha-Chlordane	0.0018	0.018
gamma-Chlordane	0.0042	0.0545
p,p'-DDT	0.126	0.940
Endosulfan,B	0.014	0.111

# Table 6-9

# CURRENT SURFACE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37

 $(\mu g/g)$ 

Chemical	Average	Maximum	
Semivolatile Organics			
Bis(2-ethylhexyl)phthalate	0.310	1.30	
Butylbenzylphthalate	0.192	0.600	
Benzo(b)fluoranthene	0.082	0.082	
Fluoranthene	0.081	0.081	
Pyrene	0.090	0.090	
Other Organics			
Total petroleum hydrocarbons	215	1,800	

 $^{^{\}rm a}$  Total chromium assumed to be 90% Cr III and 10% Cr VI.

**Table 6-10** 

#### FUTURE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37

 $(\mu g/g)$ 

Chemical	Average	Maximum	
Metals			
Aluminum	8,130	14,000	
Antimony	0.617	5.74	
Arsenic	6.37	14.0	
Barium	33.2	200	
Beryllium	0.344	0.581	
Cadmium	3.99	64.3	
Calcium	793	4,710	
Chromium ^a	16.6	73.3	
Cobalt	7.15	21.1	
Copper	17.9	91.4	
Iron	14,460	66,000	
Lead	37.5	260	
Magnesium	2,190	3,650	
Manganese	135	346	
Nickel	13.0	43.6	
Potassium	1,240	2,640	
Sodium	125	538	
Vanadium	19.5	36.3	
Zinc	307	2,300	
PCBs			
PCB-1254	0.070	2.00	
PCB-1260	0.529	6.30	
Pesticides			
alpha-Chlordane	0.0018	0.018	
gamma-Chlordane	0.0042	0.0545	
p,p'-DDT	0.081	0.940	

## FUTURE SOIL COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37

 $(\mu g/g)$ 

Chemical	Average	Maximum
Endosulfan, B	0.011	0.111
Semivolatile Organics		
Bis(2-ethylhexyl)phthalate	0.244	1.30
Butylbenzylphthalate	0.178	1.05
Di-n-octylphthalate	0.074	0.120
Benzo(b)fluoranthene	0.082	0.082
Fluoranthene	0.081	0.081
Pyrene	0.090	0.090
Other Organics		
Total petroleum hydrocarbons	.137	1,800

a Total chromium assumed to be 90% Cr III and 10% Cr VI.

Table 6-11

SEDIMENT COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37  $(\mu g/g)$ 

	(μg/g)	
Chemical	Average	Maximum
Metals		
Antimony	0.74	1.72
Arsenic	16.4	37.4
Barium	37.7	72.9
Beryllium	0.68	1.09
Cadmium	2.50	2.50
Calcium	2,710	4,650
Chromium ^a	7.94	10.1
Cobalt	11.2	25.3
Copper	9.01	15.4
Iron	13,400	26,500
Lead	20.9	39.2
Magnesium	68,100	203,000
Manganese	666	1,680
Nickel	12.1	20.7
Selenium	0.351	0.852
Vanadium	13.2	21.8
Zinc	49.2	72.9
Pesticides		
alpha-BHC	0.0097	0.027
gamma-Chlordane	0.190	0.190
p,p'-DDE	0.221	0.345
Endosulfan, B	0.001	0.001
Endrin	0.024	0.024
Heptachlor epoxide	0.058	0.114
Semivolatile Organics		
Fluoranthene	0.207	0.290
Pyrene	0.213	0.310

#### SEDIMENT COPC EXPOSURE POINT **CONCENTRATIONS AT SITE A12/P36/P37** $(\mu g/g)$

Chemical	Average	Maximum
Volatile Organics		
Toluene	0.012	0.030
Other Organics		
Total petroleum hydrocarbons	64.7	174

a  $_{Total}$  chromium assumed to be 90% Cr III and 10% Cr VI.

#### UNFILTERED GROUNDWATER COPC EXPOSURE POINT CONCENTRATIONS AT SITE A12/P36/P37 (µg/L)

Chemical	Average	Maximum
Metals		
Arsenic	23.6	100
Lead	8.80	29.8
Zinc	95.4	282
Other Organics		
Total petroleum hydrocarbons	1,122	1,930

#### **Table 6-13** FILTERED GROUNDWATER COPC **EXPOSURE POINT CONCENTRATIONS** SITE A12/P36/P37 $(\mu g/L)$ Maximum Chemical Average Metals 1.13 2.14 Arsenic 2.5a 2.5a Lead 71.9 71.9 Zinc Other Organics 1,122 1,930 Total petroleum hydrocarbons

a Value equals one-half the quantitation limit.

### SITE A12/P36/P37 TRESPASSER EXPOSURE:

## PATHWAYS 1A AND 1C - INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL AND SEDIMENT

(ADOLESCENT SITE VISITORS)

Equation:

Intake  $(mg/kg-day) = \frac{CS \times IR \times RAF \times CF \times FI \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/soil/day)
RAF = Relative Absorption Factor (unitless)
CF = Conversion Factor (10⁻⁶ kg/mg)

FI = Fraction Ingested from Contaminated Source (unitless)

EF = Exposure Frequency (day/years) ED = Exposure Duration (years)

BW = Body Weight (kg)
AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in surface soil or sediment.
		RME	Maximum observed concentration in surface soil or sediment.
IR	Adolescent	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
RAF	Adolescent	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year for soil (site-specific information and professional judgment)
			30 days/year for sediment (site-specific information and professional judgement)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989h)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

### SITE A12/P36/P37 TRESPASSER EXPOSURE:

## PATHWAYS 1B AND 1D - DERMAL CONTACT WITH CHEMICALS IN SURFACE SOIL AND SEDIMENT (ADOLESCENT SITE VISITORS)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)
CF = Conversion Factor (10⁻⁶ mg/kg)

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentrations in surface soil or sediment.
		RME	Maximum observed concentration in surface soil or sediment.
ABS	Adolescent	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d).
SA	Adolescent	Average/RME	4,100 cm ² (estimated to be 25% of the 95th percentile total body surface area for males 6-17 years old; USEPA 1992d)
AF	Adolescent	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year for soil (site-specific information and professional judgment)
			30 days/year for sediment (site-specific information and professional judgment).
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW.	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989h)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Kev:

#### SITE A12/P36/P37 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2A - INCIDENTAL INGESTION OF CHEMICALS IN SURFACE SOIL (ADULTS AND CHILDREN)

Equation:

Intake (mg/kg-day) = CS x IR x RAF x CF x FI x EF x ED BW x AT

where:

= Chemical Concentration in Soil or Sediment (mg/kg) CS

= Ingestion Rate (mg/soil/day)

RAF = Relative Absorption Factor (unitless)

CF

= Conversion Factor (10⁻⁶ kg/mg) = Fraction Ingested from Contaminated Source (unitless)

EF = Exposure Frequency (day/years) ED = Exposure Duration (years)

BW = Body Weight (kg)

= Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentration in soil
		RME	Maximum observed concentration in soil
IR	Adult	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
	Child	Average/RME	200 mg/day (age groups less than 6 years old; USEPA 1991a)
RAF	Adult/Child	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adult/Child	Average/RME	1.0 (professional judgment)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)
ED	Adult	Average/RME	30 years (90th percentile time spent living at one residence; USEPA 1991a)
	Child	Average/RME	6 years (entire duration of age group)
BW	Adult	Average/RME	70 kg (average; USEPA 1991a)
	Child	Average/RME	15 kg (USEPA 1991a)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

# SITE A12/P36/P37 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2B - DERMAL CONTACT WITH CHEMICALS IN SURFACE SOIL (ADULTS AND CHILDREN)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)
CF = Conversion Factor (10⁻⁶ mg/kg)

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
CS	Adult/Child	Average	Average concentration in soil
	^	RME	Maximum observed concentration in soil
ABS	Adult/Child	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d)
SA	Adult	Average/RME	5,700 cm ² (estimated to be 25% of the total body surface area; USEPA 1992d)
	Child	Average/RME	$3,200~\text{cm}^2$ (estimated to be 40% of the total body surface area; USEPA 1992d)
AF	Adult/Child	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adult/Child	Average/RME	1.0 (professional judgment)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)
ED	Adult	Average/RME	30 years (90th percentile time spent living at one residence; USEPA 1991a)
	Child	Average/RME	6 years (entire duration of age group)
BW	Adult	Average/RME	70 kg (USEPA 1991a)
	Child	Average/RME	15 kg (USEPA 1991a)
АТ	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

#### SITE A12/P36/P37 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2C - INCIDENTAL INGESTION OF CHEMICALS IN SEDIMENT (ADOLESCENTS)

Equation:

Intake (mg/kg-day) = CS x IR x RAF x CF x FI x EF x ED

where:

= Chemical Concentration in Soil or Sediment (mg/kg)

IR = Ingestion Rate (mg/soil/day)

RAF

CF

= Relative Absorption Factor (unitless)
= Conversion Factor (10⁻⁶ kg/mg)
= Fraction Ingested from Contaminated Source (unitless)

= Exposure Frequency (day/years) EF

= Exposure Duration (years) ED

= Body Weight (kg)

= Averaging Time (period over which exposure is averaged, in days)

Variable	Receptor	Case	Value (Rationale/Source)
cs	Adolescent	Average	Average concentration in sediment
		RME	Maximum observed concentration in sediment
IR	Adolescent	Average/RME	100 mg/day (age groups greater than 6 years old; USEPA 1991a)
RAF	Adolescent	Average/RME	Chemical-specific value (USEPA 1989c)
FI	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year (USEPA 1991a)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989h)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

# SITE A12/P36/P37 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 2D - DERMAL CONTACT WITH CHEMICALS IN SEDIMENT (ADOLESCENTS)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CS \times ABS \times CF \times SA \times AF \times FC \times EF \times ED}{BW \times AT}$ 

where:

CS = Chemical Concentration in Soil (mg/kg)

ABS = Absorption Factor (Unitless)

 $CF = Conversion Factor (10^{-6} mg/kg)$ 

SA = Skin Surface Area Available for Contact (cm²/event)

AF = Soil to Skin Adherence Factor (mg/cm²)

FC = Fraction of contacted soil/sediment from contaminated area (Unitless)

EF = Exposure Frequency (events/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (period over which exposure is averaged, in days)

		<del></del>	
Variable	Receptor	Case	Value (Rationale/Source)
CS	Adolescent	Average	Average concentration in sediment.
		RME	Maximum observed concentration in sediment.
ABS	Adolescent	Average/RME	1% for cadmium; 6% for PCBs (USEPA 1992d).
SA	Adolescent	Average/RME	4,100 cm ² (estimated to be 25% of the 95th percentile total body surface area for males 6-17 years old; USEPA 1992d)
AF	Adolescent	Average/RME	1.0 mg/cm ² (USEPA 1992d)
FC	Adolescent	Average/RME	0.5 (professional judgment)
EF	Adolescent	Average/RME	100 days/year (site-specific information and professional judgment)
ED	Adolescent	Average/RME	12 years (entire duration of age group)
BW	Adolescent	Average/RME	45 kg (average for adolescents 6-17 years old; USEPA 1989h)
AT	Adolescent	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

# SITE A12/P36/P37 FUTURE RESIDENTIAL EXPOSURE: PATHWAY 5A - INGESTION OF CHEMICALS IN DRINKING WATER (ADULTS AND CHILDREN)

Equation:

Absorbed Dose (mg/kg-day) =  $\frac{CW \times IR \times EF \times ED}{BW \times AT}$ 

where:

CW = Chemical concentration in groundwater (mg/L)

IR = Ingestion rate (L groundwater/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (days)

Variable	Receptor	Case	Value (Rationale/Source)
CW	Adult/Child	Average	Average concentration in groundwater.
		RME	Maximum observed concentration in groundwater
IR	Adult	Average/RME	2 L/day (90th percentile; USEPA 1989h, 1991a)
	Child	Average/RME	1 L/day (default value; USEPA 1989h)
EF	Adult/Child	Average/RME	350 days/year (USEPA 1991a)
ED	Adult	Average/RME	30 years (90th percentile time at one residence; USEPA 1991a)
	Child	Average/RME	6 years (entire duration of age group; USEPA 1991a)
BW	Adult	Average/RME	70 kg (USEPA 1991a)
	Child	Average/RME	15 kg (USEPA 1991a)
AT	Adult/Child	Average/RME	Pathway-specific period of exposure for noncarcinogenic effects (i.e., ED x 365 days/year), and 70-year lifetime for carcinogenic effects (i.e., 70 years x 365 days/year) (USEPA 1989)

Key:

EPA = United States Environmental Protection Agency.

#### SITE A12/P36/P37 RELATIVE ABSORPTION FACTORS FOR INGESTION OF CONTAMINATED SOILS

Chemical Classification	Absorption Factor	Source	
Volatile organic compounds	1.00	USEPA 1989c	
Semivolatile compounds			
PAHs and Phthalates	1.00	USEPA 1989c	
PCBs	0.30	USEPA 1989c	
Pesticides		· · · · · · · · · · · · · · · · · · ·	
High sorption to soil	0.30	USEPA 1989c	
Low sorption to soil	1.00	USEPA 1989c	
Inorganics			
Lead			
Adults	0.30	USEPA 1989c	
Children	0.50	USEPA 1989c	
All other metals	1.00	USEPA 1989c	

#### Key:

PAH = Polycyclic aromatic hydrocarbons. PCBs = Polychlorinated biphenyls.

		L	Table 6-22			
SUMMARY	Y OF EX	CESS CANCER R	SUMMARY OF EXCESS CANCER RISKS ASSOCIATED WITH SITE A12/P36/P37	ED WITH SITE A	12/P36/P37	
			Receptor			
Pathway	Case	Adult	Adolescent	Child	Risk Contributions by Exposure Route ^a	Risk Contributions by Chemical ^a
Exposure Pathways Potentially Complete Under Current Site Conditions	Jurrent Site	Conditions				
Trespasser Soil Contact	RME	I	1.1 x 10 ⁻⁵	Ī	Dermal Contact - 77%	PCBs - 86%
	Average	I	1.8 x 10 ⁻⁶	1	Soil Ingestion - 23%	Arsenic - 12%
						Beryllium - 1%
Trespasser Sediment Contact	RME	I	1.1 x 10 ⁻⁶	I	Sediment Ingestion - 100%	Arsenic - 93%
	Average	I	5.1 x 10 ⁻⁷	1		Beryllium - 6%
Exposure Pathways Potentially Complete Under Possible Future Site Conditions	ossible Fut	ure Site Conditions				
Future Resident Soil Contact	RME	1.6 x 10 ⁻⁴	I	1.2 x 10 ⁻⁴	Dermal Contact - 82%	PCBs - 89%
	Average	1.8 x 10 ⁻⁵	1	2.1 x 10 ⁻⁵	Soil Ingestion - 18%	Arsenic - 9%
						Beryllium - 1%
Future Resident Sediment Contact	RME	I	3.8 x 10 ⁻⁶	1	Sediment Ingestion - 100%	Arsenic - 93%
	Average	1	1.7 x 10 ⁻⁶	1		Beryllium - 6%
Future Residential Groundwater Usage, Unfiltered	RME	2.1 x 10 ⁻³	1	9.9 x 10 ⁻⁴	Water Ingestion - 100%	Arsenic - 100%
	Average	5.0 x 10 ⁻⁴	1	2.3 x 10 ⁻⁴		
Future Residential Groundwater Usage, Filtered	RME	4.5 x 10 ⁻⁵	1	2.1 x 10 ⁻⁵	Water Ingestion - 100%	Arsenic - 100%
	Average	$2.4 \times 10^{-5}$	1	1.1 x 10 ⁻⁵		

 $^{\mathrm{a}}$  RME case for the receptor showing the greatest risk.

d paper			Ţ	Table 6-23			
	SUMMARY OF ESTIMATED HAZARD INDI	ARD IND	ICES FOR NONC	ARCINOGENIC	C EFFECTS ASS	CES FOR NONCARCINOGENIC EFFECTS ASSOCIATED WITH SITE A12/P36/P37	12/P36/P37
				Receptor			
	Pathway	Case	Adult	Adolescent	Child ^a	Risk Contributions by Exposure Route ^b	Hazard Index by Chemical ^b
	Exposure Pathways Potentially Complete Under Current Site Conditions	Surrent Site	Conditions				
	Trespasser Soil Contact	RME	Î	0.12		Dermal Contact - 66%	
		Average	1	0.16	1	Soil Ingestion - 34%	
	Trespasser Sediment Contact	RME	1	0.014	1	Sediment Ingestion - >99%	
		Average	1	0.007	1	Dermal Contact - <1%	ċ
	Exposure Pathways Potentially Complete Under Possible Future Site Conditions	ossible Fut	re Site Conditions	٠			
	Future Resident Soil Contact	RME	77.0	1	3.7	Dermal Contact - 63%	PCB-1254 - 1.6
		Average	19:0	1	0.49	Soil Ingestion - 37%	Cadmium - 0.8
	Future Resident Sediment Contact	RME	1	0.047	1	Sediment Ingestion - >99%	1
		Average	1	0.022	1	Dermal Contact - <1%	
colog	Future Residential Groundwater Usage, Unfiltered	RME	9.2	1	21	Water Ingestion - 100%	Arsenic - 21
y and		Average	2.2	1	5.0		
d envi	Future Residential Groundwater Usage, Filtered	RME	0.20	1	0.46	Water Ingestion - 100%	
ronn		Average	0.11	1	0.26		
nent							

A Hazard indices for the child were calculated using subchronic RfDs.
 B RME case for the receptor showing the greatest risk.
 C Hazard indices are based on RfDs taken from MDEP Residential Shortform (MDEP 1992) which are not EPA approved.

#### COMPARISON OF ESTIMATED RISKS FROM ARSENIC: ROUTINE EXPOSURES OF THE GENERAL POPULATION vs. POTENTIAL SITE-RELATED EXPOSURES

	Cancer Risk	Hazard Index
Routine food and drinking water consumption (25-50 µg/day ^a )	6 x 10 ⁻⁴ to 1 x 10 ⁻³	1.2 to 2.4
Ingestion of drinking water at the MCL (50 $\mu$ g/L ^b )	2.5 x 10 ⁻³	4.8
Ingestion of Site Groundwater Unfiltered (100 μg/L) Filtered (2.14 μg/L)	2.1 x 10 ⁻³ 4.5 x 10 ⁻³	9.1 0.20
Ingestion of Sediment (37 μg/g)	3.5 x 10 ⁻⁶	0.04
Ingestion of Soil (14 μg/g)	1.5 x 10 ⁻⁵	0.06

a ATSDR 1992a, WHO 1991.

b USEPA 1991b.

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#### 7. ECOLOGICAL RISK ASSESSMENT

#### 7.1 INTRODUCTION

General Volume I, Section 5 describes the general ecological risk assessment approach for both the P11/P13 and A12/P36/P37 sites. This ecological risk assessment for the A12/P36/P37 site includes additional site-specific information, and presents a qualitative and quantitative assessment of the potential ecological risks from site-related contaminants.

Consistent with EPA guidance (USEPA 1992e), the ecological risk assessment is divided into six subsections. Section 7.1 describes the site and the goals of this risk assessment. Section 7.2 discusses problem formulation, and identifies the site habitats and special ecological features, contaminants of ecological concern, potential exposure pathways, ecological endpoints, and an ecological conceptual site model. Section 7.3 is an exposure assessment providing quantitative or qualitative exposure scenarios and estimates for selected ecological receptors. Section 7.4 is an ecological effects assessment summarizing toxicity reference values for selected ecological receptors. A risk characterization combining the information from the exposure assessment and ecological effects assessment to obtain estimates of ecological risk posed by the contaminants of ecological concern is provided in Section 7.5, and Section 7.6 provides conclusions and recommendations of the risk assessment. Figures and tables cited in the text are collected at the end of Section 7.

#### 7.1.1 Site Description

The A12/P36/P37 site is located in the southeast corner of the southern section of the Annex. Buildings T104 and T106 on Sites P36 and P37, respectively, were constructed in 1958 by Raytheon, Inc. (Raytheon), originally to fulfill contracts with the USAF. Building T104 was built with its own septic system and leach field on the south side. Based on contract information, Building T104 was apparently used by Raytheon through the 1960s for research and development of missile guidance and radar systems, and for the manufacture of electronic equipment. Building T106, which is located approximately 300 feet east of Building T104, was used for assembly of electronic equipment during this time. During the 1970s, the buildings were used by Natick Laboratories Air Drop Engineering Laboratory for equipment development. The buildings were not used after 1980.

In 1983, Fort Devens began using the area just east of Building T104 (Site A12) for temporary storage of transformers prior to their removal from the Annex. In July 1985, personnel from Fort Devens discovered that a transformer, damaged by bullets, had leaked approximately 100 to 200 gallons of transformer oil to the ground. The fluid remaining in the transformer and all visibly contaminated soil in the release area were removed shortly thereafter, and additional soils were removed later in 1985 and 1986; analytical results from sampling conducted after the removals indicated that PCBs were present at concentrations less that 4 ppm. In 1988, two underground fuel oil storage tanks were removed from the site, a

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10,000-gallon tank attached to Building T104 and a 1,000-gallon tank attached to Building T106. The smaller tank, which was in poor condition, had apparently leaked oil to the surrounding soil. Fuel-contaminated soil was removed, and the tank excavations were backfilled with clean soil. As a result of these known releases and past site activities, soils are contaminated with metals, PCBs, pesticides, and petroleum hydrocarbons.

The ecological assessment for the A12/P36/P37 site was initiated with an ecological field survey conducted by E & E biologists in June 1993. The ecological survey was intended to provide a descriptive characterization, including information on upland, wetland, and aquatic habitats on and adjacent to the site, and a general map of these habitat types, to support this ecological risk assessment. Additional information is provided in earlier sections of this report, which describe site contaminants, geology, hydrology, soils, and other site characteristics. To avoid redundancy, reference is made to these sections, and to the human health risk assessment, when appropriate.

Site A12/P36/P37 is shown on Figure 7-1. The site is 18.4 acres in size; 13.8 acres are upland and 4.6 acres are wetland. Other pertinent aspects of the physical setting of Site A12/P36/P37 are described in Section 1.

#### 7.2 PROBLEM FORMULATION

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA 1992e). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site are then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

The problem formulation is based on information collected during the site-specific ecological characterization and hydrogeological studies, and the chemical data provided from the SI sampling effort. This phase of the ecological assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints; and the conceptual model.

#### 7.2.1 Ecosystems of Concern

In conjunction with the SI report, field studies were conducted and the ecology of Site A12/P36/P37 and surrounding areas (18.4 acres) was characterized. This characterization involved the identification of plant and animal communities as well as observations of any actual or potential effects of chemical and/or physical stress on these biological resources. The entire ecological characterization of Site A12/P36/P37 is presented in Section 3 of this RI report. In general, five different plant community types were identified; four upland and one wetland communities (see Figure 7-1). The following provides a brief description of these communities, principal habitats, aquatic resources, and species of concern located in the general vicinity of Site A12/P36/P37.

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#### 7.2.1.1 Open/Disturbed Area (OD)

This cover-type is located around the abandoned buildings, roads and parking lot in the center of the site (see Figure 7-1). The eastern portion of this area consists of herbaceous plants such as asters, goldenrods, whorled loosestrife, sweet white clover, various grasses, and cinquefoil. The western portion of this disturbed area is less open and consists of grey birch and fire cherry. However, low blueberry, sweet fern, red oak, paper birch, big tooth aspen, scotch pine, and white pine saplings also occur in this portion of the site. In addition, a few cottonwood trees are scattered along the edges of the disturbed area.

The dense herbaceous growth in this area provides protective cover for a variety of small mammals and songbirds. In addition, the vegetation provides seeds and berries that can be eaten by many species of birds and small mammals.

No signs of stressed vegetation or wildlife were observed in this area during the field survey.

#### 7.2.1.2 Forest Uplands (MF, PP, and OF)

Three separate habitat areas characterized as forest are located on the A12/P36/P37 site (see Figure 7-1). The first area, a mixed forest (MF), occupies the northeast portion of the site adjacent to an open water emergent wetland. The second area, an oak forest (OF), occupies the western edge of the site. The third area, a pine plantation (PP), occupies the northern and southern edges of the site.

The mixed forest is dominated with densely growing white pines and a few white spruce, red oak and red pine. The understory and ground layer consist of overstory saplings, iron wood, low blueberry, Canada mayflower, wood fern, sassparilla, various grasses, bracken fern and star flower.

The oak forest is dominated by red and scarlet oak, as well as some scattered red maple. The relatively dense understory consists of overstory saplings, sweetfern, and low blueberry. A heavy mat of leaf litter covers the ground and limits the herbaceous layer to scattered partridge berry, bracken fern, and grasses.

The pine forest is dominated by red pine, but white pine, red oak, and scarlet oak trees are also present. The relatively dense understory and ground layer includes low blueberry and overstory regeneration, various mosses, partridge berry, bracken fern, and pink ladyslipper.

In general, forested uplands provide a variety of food items to a large number of species and are considered high-quality wildlife habitats. Maple seeds, buds, and flowers provide food for songbirds and small mammals. Young maple trees are favorite nesting sites for many birds (Martin et al., 1951). Oak acorns are a valuable food source that are heavily utilized during fall and winter months by upland gamebirds (ruffed grouse and turkey), small mammals and white-tailed deer (Martin et al., 1951). In addition, the seeds, needles and

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wood of pine are important as food for upland game birds, songbirds, small rodents and porcupines. Also, pines provide excellent cover for gamebirds and deer (Martin et al. 1951).

No signs of stressed vegetation or wildlife were noted in these areas during the field survey.

#### 7.2.1.3 Open Water/Emergent Wetland (OW)

This wetland is located on the northern end of the site (see Figure 7-1) and includes only one cover type: open water emergent wetland (OW). The vegetation is concentrated along the edges of the pond and includes scattered hemlock, speckled alder, red maple saplings, and a variety of herbaceous and emergent plants, such as water lilies, cattails, jewel weed, sensitive fern, sedges, slender-leaved iris, boneset, skunk cabbage, and bulrushes.

Open-water wetlands provide drinking water, food, breeding areas, and shelter for both permanent residents as well as animals that visit from other habitats. A variety of amphibians, reptiles, waterfowl, fish, piscivorous birds, and raptors can be found in this type of community. In addition, the emergent vegetation provides cover and food for the wildlife species that frequent this area. However, the size of the wetland limits the number of individuals that can be supported.

#### 7.2.1.4 Aquatic Resources

Surface runoff in the area flows northeast across the site towards Marlboro Brook. Marlboro Brook and the emergent riparian wetland associated with it are located approximately 400 feet north of the site.

#### 7.2.1.5 Species of Concern

One federally listed and six state-listed species are known to occur within 1.5 miles of the A12/P36/P37 site (see Table 7-1). However, no species of concern were observed on site during the field surveys, nor are they expected to occur because of the small size of the site and the lack of suitable habitat.

#### 7.2.2 Potential Stressors, Exposure Pathways, and Ecological Effects

The next step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants from the site to the ecosystems of concern are discussed, and potential ecological effects are summarized.

#### 7.2.2.1 Potential Stressors

Based on the field surveys and data collected during the SI sampling effort, other than the human disturbance/development, there appear to be only chemical stressors present at the A12/P36/P37 site. Since the human activities have been present for a number of years, the

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vegetation and wildlife reflect these changes. Therefore, the presence of human activity in the area is not considered a physical stressor to the ecological community, but rather a defining character of the existing community.

The chemical stressors present within Site A12/P36/P37 include the contaminants of potential ecological concern identified below. In general, these contaminants could include: metals, pesticides, and other organics in surface soils, subsurface soils, surface water, sediments, and groundwater.

Selection of contaminants of potential concern (COPCs) for ecological receptors was based on the general screening criteria outlined in Volume I, Sections 4 and 5. These screening criteria include local background concentrations and ecological risk-based criteria derived or obtained from published sources. The use of background concentrations and risk-based criteria to screen the data allows identification of COPCs to which ecological receptors may be highly sensitive. Since the application of these criteria is extensively discussed in the previously cited sections, they are not discussed in the ecological risk assessment for the A12/P36/P37 site. Section 6 of this report provides a summary of the chemical data and presents comparisons to local background concentrations.

Potentially affected media at the A12/P36/P37 site include surface water, sediments, surface soils, subsurface soils, and groundwater. The results of screening chemicals in these media for exceedances of ecological criteria are provided below.

#### **Surface Water**

Three surface water samples from Marlboro Brook and its associated wetland near Site A12/P36/P37 were collected for analysis in the SI sampling phase. These samples (E3-P37-D01, E3-P37-D02 and E3-P37-D03) were collected from locations adjacent to and downstream from the site.

The surface water sampling locations are shown on Figure 7-1, and the chemical results are summarized in Section 6.

A total of 10 metals were detected at levels above background in the surface water of the wetlands areas or streams near the A12/P36/P37 site. The metals include aluminum, arsenic, barium, cobalt, iron, lead, manganese, nickel, vanadium, and zinc. In addition, bis(2-ethylhexyl) phthalate was also detected in one sample in the surface water (see Section 6). Table 7-2 summarizes the results of screening chemicals with ecological risk-based criteria. Lead and zinc were selected as COPCs. The highest concentration of lead and zinc were found at station E3-P37-D01. The remaining chemicals were not considered of concern because exceedances of background criteria were few, the magnitude of exceedances was not great, or one of the following reasons:

 The AWQC for aluminum is considered problematic by the EPA since the criterion is frequently exceeded in pristine waters where the biota are unimpaired. The toxicity of aluminum is affected by a number of factors that are not reflected in the criterion, such as the

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chemical form of the aluminum, the presence of complexing ligands and organic acids, and the concentration of silicon;

- According to EPA (1986), black or brown swamp waters may contain iron concentrations of several mg/L, but this iron form is naturally occurring and has little effect on aquatic life;
- According to EPA (1986), soluble barium concentrations of less than or near 50 mg/L are not considered toxic to aquatic organisms; and
- It is unlikely that the aluminum or iron detected in unfiltered surface water are site-related contaminants, because these elements are naturally abundant in rocks, soils, and sediments.

#### **Sediments**

A total of three sediment samples was collected for chemical analysis. The sediment samples were collected from the same locations as the surface water samples. The sampling locations are shown in Figure 7-1, and the chemical results are summarized in Section 6.

A total of 15 metals detected in the sediments of the nearby wetland areas and streams of Site A12/P36/P37 were found at levels elevated above local background (see Section 6). The highest concentration of most metals in Marlboro Brook occurred at station E3-P37-D03, which had a TOC concentration of 37.2% on a dry weight basis. This TOC concentration was greater than the TOC levels in the designated background sediment samples, which generally contained less than 1% TOC. Mid-basin sediment from the remote New England Lakes listed in Table J-1 of Appendix J contained 14% to 23% TOC. Therefore, given the association of metals in sediments with TOC, the New England Lakes regional background levels provide a valid comparison with levels of metals in sediments at Sudbury Annex.

Arsenic was selected as an ecological COPC. The highest concentration of arsenic was found at station E3-P37-D03. Despite some exceedances, the remaining metals that exceeded criteria were not considered ecological COPCs because exceedances of background or criteria were few, and the magnitude of exceedance was not great. In addition, the highest concentrations of these metals were within, or below, the range of regional background levels reported for remote New England lakes, and for unimpacted lakes and ponds in Massachusetts (see Table 7-4).

Organic contaminants detected in the Site A12/P36/P37 sediments include alpha-BHC, gamma-chlordane, p,p'-DDE, endosulfan B, endrin, heptachlor epoxide, fluoranthene, pyrene, and TPHC. Samples in which p,p'-DDE, fluoranthene, and pyrene were normalized for organic carbon are presented in Table 7-5. Table 7-3 summarize the results of the screening with ecological risk-based criteria. None of the organic substances were selected as ecological COPCs in the Site A12/P36/P37 sediments. The detection frequency for organics was isolated to one sample with the exception of p,p'-DDE. Moreover, none of the organics exceeded criteria normalized for organic carbon (see Table 7-5). The TPHC in the sediments

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at Site A12/P36/P37 are likely the residues of fuel spills. The sediments were analyzed for semivolatile and volatile organic compounds, and only low concentrations of PAHs were detected. Therefore, these residues are expected to be composed primarily of long-chain hydrocarbons, which are not considered to be of toxicological concern at the levels detected in the sediments.

#### Surface Soils

Twenty-two surface soil samples were collected for chemical analysis from the Site A12/P36/P37 area. These samples were collected during the site investigation sampling effort. The sampling locations are shown on Figure 7-1, and chemical results are summarized in Section 6.

A total of 17 metals detected in the surface soils of Site A12/P36/P37 were found in one or more samples at levels evaluated above background (see Section 6). These metals include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, thallium, vanadium, and zinc. The results of the comparison of these metal concentrations with ecological risk-based criteria are shown in Table 7-6. A number of metals exceeded the risk-based criteria; however, only cadmium, copper, lead, and zinc were selected as COPCs. The highest concentrations of zinc and cadmium were found at Station E4-P36-S09. The highest concentrations of copper and lead were found at Station E3-P36-S01. Chromium also exceeded the criteria and background, but it was not selected as a COPC because its restriction to one location indicates that it is of limited ecological significance at the site.

On the basis of the screening shown in Section 6, Aroclor 1260 was selected as a COPC. This compound was detected at seven or more stations and exceeded background concentrations at three or more stations. The remaining organic compounds are not considered COPCs for the following reasons:

- The detection frequencies were relatively low and mostly isolated to one or two samples;
- In general, maximum concentrations of organics were relatively low, usually much lower than 1  $\mu$ g/g; and
- The majority of these compounds (e.g., PAH and DDT and related compounds) are ubiquitous in soils. PAHs are a natural product of combustion (Eisler 1987) and could be a result of burning activities at Site P11/P13.

#### **Subsurface Soil**

Twelve subsurface soil samples were collected for chemical analyses from the A12/P36/P37 site. The sampling locations are shown on Figure 7-1, and chemical results are summarized in Section 6.

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A total of 12 metals detected in the subsurface soils of the A12/P36/P37 site were found at elevated levels when compared to background levels (see Section 6). The metals include aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, manganese, nickel, thallium and zinc. The comparison of metals concentrations to risk-based criteria are presented in Table 7-7. On the basis of the screening, cadmium and zinc were identified as COPCs. Cadmium and zinc are also COPCs in surface soil (see above).

Although 1,2-dichloroethane, di-n-octylphthalate, hexadecanoic acid, and TPHC were detected at the site, they are not considered COPCs because the maximum concentration of these compounds were relatively low and isolated to one location. Moreover, since these chemicals were not detected in surface soils, exposure to ecological receptors is likely to be minimal.

#### Groundwater

Contamination of downgradient surface water and sediment is of potential concern at Site A12/P36/P37 due to the groundwater discharge to wetland and stream habitats. However, elevated levels of metals and low levels of organic substances, including TPHC in the downgradient wells (see Tables 7-8 and 7-9), are not considered COPCs for ecological receptors at the site, except indirectly as a potential source of contamination to sediments or surface water downgradient from the site.

To evaluate groundwater as a potential source of contaminants of ecological concern, concentrations of chemicals exceeding background were compared to EPA Ambient Water Quality Criteria (AWQC) or other criteria (see Tables 7-8 and 7-9). Although several metals in groundwater exceeded these criteria as applied to the unfiltered groundwater (see Table 7-8) only zinc exceeded the criteria after adjustment for application to the filtered groundwater data (see Table 7-9). Since the filtered data are more relevant to interpretation of ecological risks (USEPA 1993b), zinc is the only metal in groundwater at Site A12/P36/P37 that appears to present potential risks to aquatic life in the vicinity of the site. Zinc was selected as a COPC in surface water (see above). No organic substances were detected in the filtered groundwater samples.

#### **Summary of COPCs**

The following metals and organic compounds were selected as ecological COPCs in surface water, sediments, and surface soils potentially affected by the activities at Site A12/P36/P37 (see Table 7-10): lead and zinc in the surface water; arsenic in the sediments; cadmium, copper, lead, zinc, and Aroclor 1260 in the surface soils. No other chemicals were selected as COPCs for this ecological assessment.

#### 7.2.2.2 Exposure Pathways

Several ecologically relevant migration pathways for contaminants exist at the A12/P36/P37 site (see Figure 7-2). Chemical contaminants can adversely affect plants and animals in surrounding habitats via the food chain. Moreover, wildlife in the A12/P36/P37

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area may have incidental contact with or ingestion of contaminants while foraging, nesting, or engaging in other activities at adjacent wetland areas.

Upon their release, some of the site contaminants are persistent and may be transformed to more bioavailable forms and mobilized in the food chain. Mobilization of contaminants in the terrestrial food chain could occur through the following pathways:

- · Root uptake from contaminated soil by herbaceous plants;
- Contact and absorption, incidental ingestion, and feeding on contaminated food by invertebrates;
- · Drinking of contaminated surface water by wildlife; and
- Consumption of contaminated vegetation or animal prey or incidental ingestion of contaminated soil by wildlife.

Like the terrestrial food chain, contaminants could be mobilized in the aquatic food chain through the following pathways:

- · Uptake from surface water or sediment by aquatic macrophytes;
- Contact and absorption, incidental ingestion, and feeding on contaminated food by aquatic invertebrates;
- Drinking of contaminated surface water by aquatic and semi-aquatic wildlife; and
- Consumption of contaminated vegetation or animal prey or incidental ingestion of contaminated sediment by aquatic and semi-aquatic wildlife.

Based on these pathways, the following general classes of ecological receptors have the potential for being exposed to contaminants at the A12/P36/P37 site:

- Terrestrial and aquatic plants growing in and around the area;
- Terrestrial invertebrates likely to occur in an open disturbed environment, and benthic or other aquatic invertebrates in the wetlands;
- Birds that forage or nest within the area;
- Small mammals that reside and/or feed within the area; and
- Other wildlife species (e.g., carnivores) that feed within the area.

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#### 7.2.2.3 Ecological Effects

As discussed earlier, several site contaminants are present in soil, sediment, and surface water and exceed ecological concern levels and, therefore, may have adverse effects on biota in the vicinity of A12/P36/P37 site. These COPCs include: arsenic, cadmium, copper, lead, zinc, and Aroclor 1260.

PCBs have a tendency to bioaccumulate in the food chain causing reproductive effects in animals. Excessive levels of zinc in plants can cause stunted growth, but plants and animals are relatively tolerant of high zinc levels. Excessive levels of arsenic in plants can adversely affect growth. In animals, arsenic is an acute poison. Chronic exposure to arsenic can lead to appetite loss, reduced growth, blindness, degenerative changes in the liver and kidney, and heart damage. Lead is of ecological concern due to its tendency to persist in the environment. Lead generally is not highly mobile in the environment but may accumulate in tissues such as bone and liver. Excessive copper inhibits growth of vegetation. Chronic exposure to copper causes hepatic effects in animals.

#### 7.2.3 Ecological Endpoints

Based on the considerations shown in Tables 7-11 and 7-12 and the potential pathways and receptors identified and described in Section 7.2.2, detrimental effects (i.e., reduced survival, growth, or reproduction, with potential impacts on populations) on vegetation, aquatic invertebrates, small mammals, birds, and carnivores were selected as the assessment endpoints for the A12/P36/P37 ecological risk assessment.

Due to the numerous wildlife species found in the general vicinity of A12/P36/P37, it was necessary to select a few assessment endpoint species that are thought to be representative of the local wildlife populations that would utilize and frequent the area. Selection of the assessment endpoints involved determining the basic trophic structure of the communities and listing various species in each trophic level that are common to the site. These trophic level groups were then divided into groups of species that have a similar composition of dietary food items (e.g., percent of fish, insects, birds, in diet), and a representative endpoint species was selected. The species were selected based on their potential exposure (i.e., site usage, food habitats, home range size) and susceptibility to adverse effects of the site contaminants. In addition, if a species of social significance (i.e., game species or species of concern) is known to occur in the area, that species or a surrogate species with similar habits and diet may be selected as an endpoint.

#### 7.2.3.1 Aquatic and Semi-Aquatic Endpoint Species

Following is a brief description of the habitat requirements and diet of the aquatic and semi-aquatic endpoint species selected for the A12/P36/P37 site. In addition, the reasons for selection of these species are discussed.

Aquatic Invertebrates. The wetland area to the northeast of the A12/P36/P37 site supports a community of benthic invertebrates; and numerous other aquatic invertebrates occur in Marlboro Brook.

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Aquatic invertebrates form the base of the aquatic food chain, and are sensitive indicators of environmental contamination. Therefore, the community of aquatic invertebrates was selected as an assessment endpoint. The measurement endpoints for aquatic invertebrates include sediment or surface water toxicity reference values for each contaminant, which are provided in Section 7.2.2.1.

Meadow Vole (Microtus pennsylvanicus). This common small mammal occurs throughout Massachusetts, occupying home ranges from 0.08 to 0.23 acre. The meadow vole builds extensive tunnel and runway systems for escape and nesting. It is found in a variety of habitats including freshwater marshes and meadows, borders of streams and lakes, open and wooded swamps, fields, pastures, and orchards. The meadow vole consumes mainly vegetable material especially tender grass, bulbs, cambium of roots and stems, seeds, and grains. It is active day and night throughout the year.

The meadow vole has been selected to represent the small mammal community residing in the wetlands at the P11/P13 site. The meadow vole is representative of the herbivores residing in the wetlands. Due to the size and hydrology of the wetlands (i.e., no open water), other herbivores such as muskrat are unlikely to make significant use of the area.

Measurement endpoints for the meadow vole are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

• Raccoon (Procyon lotor). This common mammal occurs throughout Massachusetts, occupying home range of greater than 100 acres. The raccoon prefers wooded areas associated with open water or wetlands and interrupted by fields. It requires habitat where cavity trees or protected areas for denning are available. The raccoon is an opportunistic omnivore consuming worms, insects, frocarrion, tender buds, shoots, grass, and human garbage. Primarily nocturnal, it remains dormant through the winter, but does not hibernate (DeGraaf and Rudis 1986).

The raccoon has been selected to represent the carnivore community at the site. Although the weasel, eimine, and mink are other predators occurring in the general vicinity, their habitat requirements (i.e., heavy cover, near water) are more specific than the raccoon's, and they are not as tolerant of human activity. The coyote and red-tailed hawk are other potential endpoint species, but their home ranges are larger than that of the raccoon, and their use of the site is not likely to be significant. Measurement endpoints for the raccoon are derived from mammalian toxicity data taken from published dose-response

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studies that relate contaminant exposure or uptake to effect on individual organisms (see Section 7.4).

#### 7.2.3.2 Terrestrial Endpoint Species

Following is a brief description of the habitat requirements and diet of the terrestrial endpoint species selected for the A12/P36/P37 site. In addition, the reasons for selection of these species are discussed.

- Herbaceous Vegetation. Plants that occur in sandy soils in the northeastern United States are likely to occur on the A12/P36/P37 site. These plants include herbaceous species that serve as an important food source for songbirds, small mammals, and larger herbivores. The measurement endpoints for terrestrial vegetation are the phytotoxicity reference values of each contaminant, which are provided in Section 7.2.2.1.
- White-Footed Mouse (Peromyscus leucopus). This common small mammal occurs throughout Massachusetts, occupying home ranges from 0.06 to 0.54 acres. It is found in a variety of habitats, including interiors and edges of deciduous and coniferous forests, scrub areas, clearings, pastures, stream-side thickets, and buildings. The white-footed mouse consumes seeds, acorns, fruit, herbaceous foliage, insects, and, occasionally, carrion. It is active throughout the year, nesting in cavities under stumps and logs and in buildings (DeGraaf and Rudis 1986).

The white-footed mouse has been selected to represent the small mammal community at the A12/P36/P37 site. As a receptor with an omnivorous diet that includes both plants and insects, the white-footed mouse is representative of herbivorous and insectivorous small mammals present within the boundaries of the A12/P36/P37 site. In addition, due to the scarcity of herbaceous plants in the vicinity, larger herbivores such as rabbits and deer are unlikely to make significant use of the area.

Measurement endpoints for the white-footed mouse are derived from rodent toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

 American Robin (*Turdus migratorius*). The American Robin is common in Massachusetts. A typical density, measured during the breeding season, is 132 birds per 100 acres, each with an approximate home range of 1/2 acre. Breeding robins prefer open woodlands, edges, clearings, fields, orchards, and shade trees in

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residential areas. Preferred food items include wild and cultivated fruits, earthworms, and insects (DeGraaf and Rudis 1986).

The robin has been selected to represent the songbird community at the site. As a receptor with an omnivorous diet that includes both plants and insects, the American Robin is representative of herbivorous and insectivorous birds present within the boundaries in the A12/P36/P37 site.

Measurement endpoints for the robin are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

• Red Fox (Vulpes vulpes). This common mammal occurs throughout Massachusetts, with home ranges of greater than 100 acres. The red fox prefers a mixture of open and forest habitats, using the edges extensively. It requires habitat where soil conditions are suitable for digging dens, but may also use existing burrows. The red fox is active throughout the year and is an opportunistic omnivore, consuming insects, birds, small mammals, amphibians, eggs, berries, and fruit. Larger mammals such as the porcupine and white-tail deer may also be included in the diet (DeGraaf and Rudis 1986).

The red fox has been selected to represent the terrestrial carnivore community at the A12/P36/P37. The coyote and red-tailed hawk are other potential endpoint species, but their home ranges are much larger than that of the red fox, and their use of the A12/P36/P37 is not likely to be significant.

Measurement endpoints for the red fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms (see Section 7.4).

#### 7.2.4 Ecological Conceptual Site Model

In accordance with recent EPA guidance (USEPA 1992e), a conceptual model was developed to evaluate how chemical stressors from the A12/P36/P37 may impact ecological components of the natural environment (see Figure 7-2). This model illustrates the relationship between the ecosystem at risk, including the assessment endpoint species, and the chemical stressors. In addition, the contaminated media, exposure routes, and environmental transport are identified in the conceptual site model.

Ecological receptors evaluated in this risk assessment include representative species of terrestrial habitats (herbaceous plants, small mammals, songbirds, and carnivores) and species of aquatic habitats, including aquatic invertebrates and semi-aquatic receptors, that are likely

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to utilize both the wetland area and the upland grassland. Effects evaluated are based on published scientific studies and include the estimated effects of the contaminants of concern on the survival, growth, and reproduction of these receptors.

#### 7.3 EXPOSURE ASSESSMENT

This section includes only site-specific information pertinent to the assessment of potential ecological exposures to contaminants at the A12/P36/P37 site. General descriptions of the exposure assessment process can be found in Volume I, Section 5. General discussions of ecosystems of concern, pathways, and COPCs at the A12/P36/P37 site are provided in Section 7.2.

#### 7.3.1 Exposure Point Concentrations

The exposure media of ecological concern at the A12/P36/P37 site include surface water, sediments, and surface soils. As in the human health risk assessment, two cases of exposure are considered: the average exposure case, and the reasonable maximum exposure (RME) case. Exposure point concentrations (EPCs) calculated for the average exposure case are the average surface water, sediment, or soil concentrations of COPCs. For the RME case, the maximum concentrations of metals and organic substances selected as COPCs were used. These values are provided in Table 7-13.

#### 7.3.1.1 Surface Water and Sediments

Because both the wetlands and Marlboro Brook ecosystems are hydrologically connected and because Marlboro Brook is a sluggish slow moving stream, these ecosystems are considered as a whole in this ecological risk assessment. Exposure concentrations for sediments were estimated from data for all sediment samples collected from the wetlands and from Marlboro Brook during the SI sampling phases. Moreover, exposure concentrations for surface waters were estimated from the SI data.

#### 7.3.1.2 Soils

Exposure point concentrations for soils were estimated from surface soil data collected from SI sampling.

#### 7.3.2 Exposure Scenarios and Pathways

As explained previously, five wildlife scenarios were selected for the quantitative ecological risk assessment: a terrestrial small mammal, a semi-aquatic small mammal, a songbird, a semi-aquatic carnivore, and a terrestrial carnivore. The terrestrial small mammal is represented by the white-footed mouse; the semi-aquatic small mammal is represented by the meadow vole; the songbird is represented by the American robin; the semi-aquatic carnivore is represented by the racoon; and the terrestrial carnivore is represented by the red fox. The exposure parameters used to estimate exposure through incidental ingestion of soil, sediment, and surface water, and exposure through the food chain for these receptors, are provided in Table 7-14.

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The exposure parameters shown in Table 7-14 were derived or obtained from EPA's wildlife exposure factors handbook (USEPA 1993c). An exposure duration of 0.66 year was used for the American robin to account for the migratory behavior of this birds (that is, one-third of the year is spent wintering away from the site).

To estimate exposure through the terrestrial and aquatic food chains, bioaccumulation factors (BAFs) for sediment and soils were derived from published sources as described in Volume I, Section 5. Using these BAFs, tissue levels in potential prey items of the endpoint species were calculated for the average exposure case (see Tables 7-15 and 7-16), and the RME case (see Tables 7-17 and 7-18).

#### 7.3.3 Exposure Estimates

Dietary exposure and exposure from ingestion of soil, sediment, or surface water for each wildlife receptor species were calculated as described in Volume I, Section 5. The estimated exposures for terrestrial herbaceous vegetation were assumed to be equal to surface soil concentrations of COPCs, as shown in Table 7-13. The estimated exposures for aquatic invertebrates were assumed to be equal to the surface water and sediment concentrations of COPCs, as shown in Table 7-13.

In cases where a particular chemical is a COPC in one or more medium but not in other media, an approach was taken to evaluate exposure only for those media where the chemical is considered a COPC.

Exposure estimates for semi-aquatic and terrestrial wildlife are shown in Table 7-19 and were calculated based on the following assumptions.

#### 7.3.3.1 Semi-Aquatic Wildlife

The meadow vole was assumed to confine its feeding activities to the wetlands. Therefore, this receptor could be exposed to COPCs occurring in surface water or sediment, either directly or indirectly via the aquatic food chain. Exposure from direct contact and ingestion was calculated for COPCs in surface water and sediment. These exposure estimates were summed together with the dietary exposure to obtain the total exposure.

The raccoon was assumed to utilize both wetland and upland habitats. Therefore, this receptor could be exposed to COPCs occurring in surface water, sediment, or soil, either directly or indirectly via the aquatic or the terrestrial food chain. Exposure from direct contact and ingestion was calculated for COPCs in all three media for the raccoon, and these exposure estimates were summed together with the dietary exposure to obtain the total exposure. It was assumed that the sediment ingestion rate was the same as the soil ingestion rate.

#### 7.3.3.2 Terrestrial Wildlife

The white-footed mouse, American robin, and red fox were assumed to confine their feeding activities to the uplands. Therefore, these receptors could be exposed to COPCs

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occurring in soil, either directly or indirectly via the terrestrial food chain. In addition, it was assumed that all of these upland species drink from surface water in the wetlands. Exposure from direct contact and ingestion was calculated for COPCs in soil and surface water for the mouse, robin, and fox. These exposure estimates were summed together with the dietary exposure to obtain the total exposure for each receptor.

#### 7.4 ECOLOGICAL EFFECTS ASSESSMENT

This section includes only site-specific information pertinent to the assessment of potential ecological effects of contaminants at the A12/P36/P37 site. General descriptions of the ecological effects assessment process can be found in Volume I, Section 5.4.

#### 7.4.1 Toxicity Reference Values

A general summary of the known adverse effects of COPCs at the A12/P36/P37 site is provided in Volume I, Section 5.4. Published toxicity values for critical effects of COPCs are also summarized in Volume I. From this summary, a mammalian toxicity benchmark value (TBV) and an avian TBV was chosen for each chemical. NOAELs were extrapolated for each endpoint species from the TBV following Opresko et al. 1994. These NOAELs are the toxicity reference values (TRVs) used to evaluate risks to each endpoint species at the A12/P36/P37 site. TRVs for wildlife are provided in Table 7-20.

Toxicity reference values for aquatic invertebrates are the chronic water quality criteria for each COPC, as shown in Table 7-2, or the sediment criteria shown in Table 7-3. As there are several proposed values for arsenic in sediment, it was necessary to choose one value as the TRV. The NOAA/ER-L of 33  $\mu$ g/g was selected as the most appropriate benthic invertebrate TRV for the site, since this value is the most conservative standard that is greater than regional background levels. The TRVs for herbaceous vegetation are the lower phytotoxicity value for zinc and the upper phytotoxicity value for lead provided in Table 7-6. The upper level was selected as the TRV for lead, because the lower value of 100  $\mu$ g/g is less than the background level of 150  $\mu$ g/g.

#### 7.4.2 Field Studies - Summary of Findings

During the field reconnaissance, no signs of stressed vegetation or wildlife or other signs of chemical contamination were noted.

A survey of the benthic macroinvertebrate community of Marlboro Brook was conducted as part of the Rapid Bioassessment Survey of the Annex (see Appendix L). The overall condition of the stream was considered to be moderately impaired at Station MB-1 (located upgradient from the site near surface water and sediment sample station E3-A11-D01). At a survey station further downstream in Marlboro Brook (Station MB-2), the overall biological condition of the stream was not considered to be impaired in comparison to a reference survey station located in Taylor Brook.

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#### 7.5 RISK CHARACTERIZATION

In this section, the ecological risks posed by COPCs at the A12/P36/P37 site are identified and summarized. Risk characterization involves two major steps: risk estimation and risk description (USEPA 1992). The risks are estimated in Section 7.5.1 using hazard quotients (HQs) calculated with estimated exposure and toxicity reference values for each endpoint species. The ratios are summarized, and the principal uncertainties of the assessment are discussed in Section 7.5.2. The ecological significance of the findings is discussed in Section 7.5.3.

#### 7.5.1 Hazard Quotients

Table 7-21 summarizes the wildlife HQs for the average exposure case and for the RME case. The wildlife HQs for the average exposure case were all less than 1, with the exception of a slight exceedance of the arsenic TRV for the meadow vole. These results indicate that the mean concentrations of these COPCs are unlikely to pose a risk to wildlife at the A12/P36/P37 site.

HQs greater than 1 were calculated for the RME case for the white-footed mouse for cadmium and zinc, for the American robin for zinc, and for the meadow vole for arsenic (see Table 7-21). These results indicate that, at their maximum concentrations, these metals in surface soil have the potential to result in adverse effects to birds and small mammals residing at the site. The HQs for the RME case for the raccoon and red fox were less than or equal to 1 for all of the COPCs. The results indicate that the COPCs are unlikely to pose a risk to these species.

Potential risks to aquatic organisms at the site are shown in Table 7-22 for the average exposure case and for the RME case. The average and maximum surface water concentrations of lead exceed the TRV, suggesting that lead may pose a potential risk to sensitive species of aquatic life. The maximum concentration of zinc exceeded the TRV, but the HQ was less than 1 for the average concentration in surface water. The HQ for arsenic in sediment was less than 1 for the average exposure case and only slightly greater than 1 for the RME case, indicating that this COPC does not pose a risk to aquatic life at A12/P36/P37.

Potential risks to terrestrial vegetation at the site are shown in Table 7-23 for the average exposure case and for the RME case. The average and maximum detected concentrations of zinc exceeded the reference values available for this contaminant (HQ greater than 1). The average concentrations of the other contaminants in soils were below the toxicity reference values (HQ less than 1), but maximum cadmium and copper concentrations exceeded the TRV. Phytotoxicity reference values were not available for Aroclor 1260 and therefore, the potential risk of this COPC to plants was not evaluated. Aroclor 1260 did not pose a risk to any of the other endpoint species; therefore, no risks to plants are anticipated.

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#### 7.5.2 Summary of Risks and Uncertainties

Potential risks of exposure to cadmium and zinc in surface soils were identified for plants, small mammals, and songbirds residing in A12/P36/P37. These risks of adverse effects were identified for the RME case. No risks of adverse effects to wildlife from any of these COPCs in surface soils were identified for the average case. Potential risks of adverse effects on aquatic invertebrates were also identified for lead and zinc in surface water.

Uncertainty in the risk estimates may arise during any stage in the ecological risk assessment process. Incorrect assumptions may be made regarding the potential effects of a stressor, the ecosystems of concern, or the species residing within those ecosystems. Generally, care was taken to fully assess and incorporate field observations into the decision process during problem formulation to minimize these uncertainties.

The principal uncertainties in the exposure assessment have to do with quantitative estimates of exposure parameters such as BAFs. These parameters typically are chemical specific, species specific, and site specific (Rowan and Rasmussen 1992). To minimize uncertainty in the selection of parameters for the exposure assessment, E & E used site specific data when available. When site-specific data were not available, exposure parameters for COPCs were taken from the literature or calculated from literature data. Data on contaminants in wild animals, as opposed to domestic or laboratory animals, were used when available. Generally, the reasonable worst case was assumed to provide a conservative estimate.

Bioavailability of lead and zinc in site surface water is an important uncertainty in the risk assessment. The EPA Ambient Water Quality Criterion for these metals are derived primarily from the laboratory bioassays in which the metal was added as an inorganic salt that readily dissociates, thus making nearly all of the lead or zinc bioavailable. However, in natural waters such as the Annex streams and wetlands, these metals occur in a variety of dissolved and particulate forms, of which only a fraction is bioavailable. High concentrations in unfiltered samples do not necessarily imply that the water contains toxic levels of zinc.

The uncertainty associated with TRV derivation is discussed in Volume I, Section 5.4.

In general, the risk assessment is likely to overestimate rather than underestimate the risks of adverse ecological effects at the site because of the conservative nature of the assumptions used.

#### 7.5.3 Ecological Significance

The A12/P36/P37 site is a potential source of environmental contamination in soil within the open disturbed area. At the maximum concentration of cadmium and zinc in soil, this contamination may present the potential for adverse toxicological effects to sensitive species of animals and plants at the site. Lead and zinc occur in surface water at levels that could adversely affect aquatic life. There do not appear to be risks to wildlife for the average exposure case at the site, nor are there significant ecological risks of arsenic contamination of sediments.

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These potential effects are considered to have minimal ecological significance for the following reasons:

- Wildlife risks were not identified for the average exposure case. The average concentrations are representative of exposure for mobile species of wildlife, such as the American robin, red fox, and raccoon. Apex predators and wildlife with large home ranges are not likely to be adversely affected due to the comparatively limited extent of contamination.
- The RME case was based on the maximum concentration detected on site. The maximum concentration of metals are located adjacent to Building T104. If sensitive species of animals or plants did reside in this area, a risk from chemical contamination could occur to individuals. The average case is more representative of exposure to the populations as a whole, however, and adverse effects at the population level are unlikely, except for plant species particularly intolerant to zinc.
- The terrestrial ecosystems in the general vicinity of the site do not appear to be impacted, as indicated by the thriving communities of plants and wildlife observed during the field surveys.
- The benthic survey of Marlboro Brook did not suggest any impairment of the biological condition of the stream downgradient from the site.
- The surface water criteria for lead and zinc were exceeded, but these criteria are overly conservative since the forms of metals at the site are likely to be less bioavailable than the forms of these metals that occur in laboratory test situations.

#### 7.6 CONCLUSIONS AND RECOMMENDATIONS

Metals and organic chemicals in soils, surface water, and sediment at the A12/P36/P37 site are not considered to pose significant risks to populations of plants or wildlife. Levels of metals in soils exceed reference values for animals and plants but primarily for the maximum detected concentrations of these chemicals. These exceedances are not likely to be ecologically significant due to the limited extent of contamination and the disturbed nature of the habitat. Lead and zinc found in the unfiltered surface water exceeds reference values for sensitive species of aquatic life. However, aquatic life in the vicinity of the site does not appear to be impacted and the lead and zinc Ambient Water Quality Criteria for aquatic life is likely to be overly conservative for the site.

No further investigations of the A12/P36/P37 site are recommended, given the minimal ecological risks that occur at the site. The site does not appear to pose threats of chemical contamination to ecological receptors that would warrant remedial action.

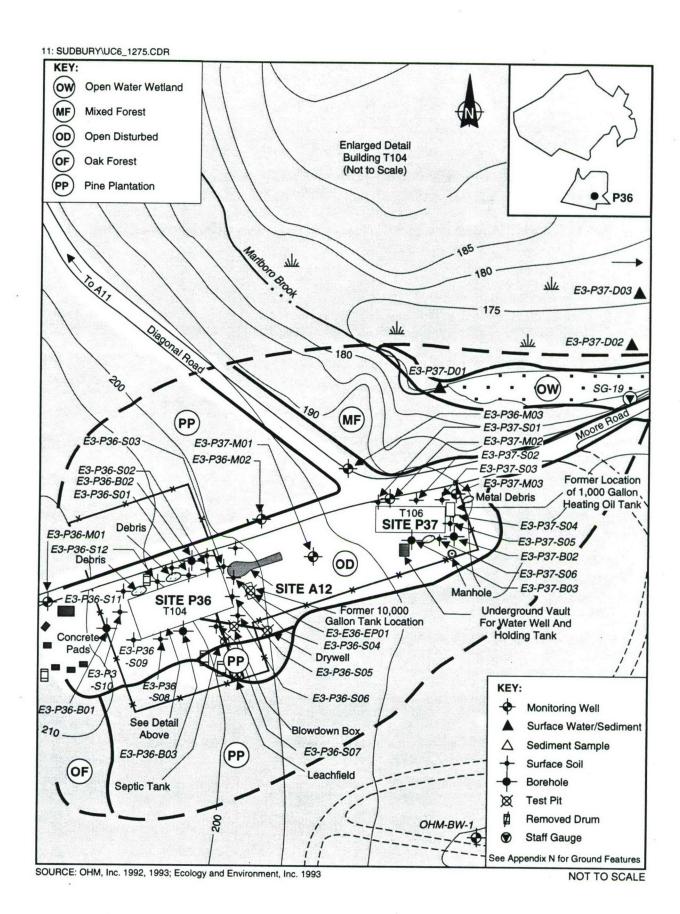


Figure 7-1 SAMPLING LOCATIONS AND COVER TYPES AT SITE A12/P36/P37

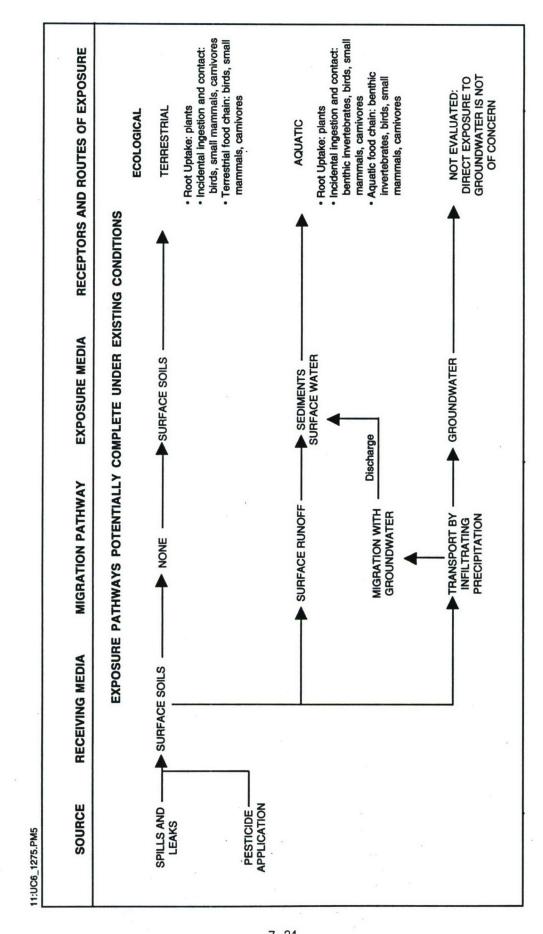


Figure 7-2 ECOLOGICAL CONCEPTUAL SITE MODEL FOR A12/P36/P37 SITE

#### Table 7-1

### FEDERAL- AND STATE-LISTED SPECIES OF CONCERN KNOWN TO OCCUR WITHIN 1.5 MILES OF THE A12/P36/P37 SITE²

	WITHIN 1.5 MILES C	1 1110 11		SILE .
Common Name	Scientific Name	Federal Status	State Status	Exposure to Site Contaminants
Birds				
Bald eagle	Haliaeetus leucocephalus	Е	Е	Minimal: Large home range
Reptiles/Amphibians				-
Spotted turtle	Clemmy gutata		SC	Minimal: Unsuitable habitat
Blandings turtle	Emydoidea blandingii		T	Minimal: Unsuitable habitat
Plants				
Midland sedge	Carex mesochorea		Е	Minimal: Potential habitat not found on site
Few-seeded sedge	Carex oligosperma		Т	Minimal: Potential habitat not found on site
Grass-leaved ladies ties	Spiralis vernalis		SC	Minimal: Potential habitat not found on site
Wood witchgrass	Panicum philadelphicum		sc	Minimal: Potential habitat not found on site

a Species listed herein include only those species considered to be endangered, threatened, or of special concern that have been sited within the last 10 years. This list excludes species considered as "watch list" species and species for which suitable habitat may exist within 1.5 miles, although occurrence of the species is not confirmed. See text for further information.

#### Key:

- E = Endangered any species that is in danger of extinction throughout all or a significant portion of its range.
- T = Threatened a species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range and any species declining or rare.
- SC = Special Concern a species suffering a decline that could threaten the species if allowed to continue unchecked or occurs in such small numbers or with such a restricted distribution or specialized habitat requirements that it could easily become threatened.

Source: Compiled by Ecology and Environment, Inc. 1994 from MNHESP 1992; Hunt 1992; Butler 1992; Cenapter 1992.

AWQC =	= Ambient Water Quality Criteria = Not available.	Quality Criteria.
11:UC6101/RC1275-V3-04/03/95-D2	-V3-04/03/95-D2	

			Table 7-7	7			
	SURFA	CE WATER	CE WATER COMPARISON TO ECOLOGICAL CRITERIA SITE A12/P36/P37 (µg/L)	O ECOLOGIC/ 6/P37	AL CRITERIA		
	Range	lge					
Chemical	Minimum	Maximum	EPA Ambient Water Quality Chronic Criteria ^a	Frequency of Exceedance of Chronic AWQC	EPA Ambient Water Quality Acute Criteria ^a	Frequency of Exceedance Acute AWQC	Exceeds Ecological Risk Criteria
Metals ^b							
Aluminum	156	7,060	87c	3/3	750 ^c	2/3	Yes
Arsenic	2.59	45.8	190 ^d	0/3	360 ^d	0/3	No
Barium	7.70	52.2	NA	NA	NA	NA	NA
Cobalt	7.51	10.2	NA	NA	NA	NA	NA
Iron	903	14,000	1,000	2/3	NA	NA	Yes
Lead	11.4	23.2	0.29e	2/3	7.34e	2/3	Yes
Manganese	124	1,700	NA	NA	NA	NA	NA
Nickel	10.6	10.6	31.8e	0/3	286 ^e	0/3	No
Vanadium	6.05	9.51	NA	NA	NA	NA	NA
Zinc	20.4	46.5	21.3e	2/3	23.54e	2/3	Yes
Semivolatile Organics							
Bis(2-ethyl-hexyl)phthalate	1.40	24.0	360 ^f	6/0	400f	0/3	No

a U.S. Environmental Protection Agency 1986d, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless otherwise

b Only metals exceeding background are shown.

Criteria are pH dependent; values are valid for pH 6.5 to 9.

d Value is for Arsenic III.

e Hardness-dependent criteria. 29.6 mg/L hardness used.

h Values are calculated from an assumed acute/chronic ratio of 10.

 $[\]mathbf{f}$  Insufficient data to develop criteria. Value presented is the Lowest Observed Effect Level.

						T	Table 7-3						
	×				SEDIMENTS (Conc	COMPARISO SITE entrations in p	MENTS COMPARISON TO ECOLOGICAL CRITERIA SITE A12/P36/P37 (Concentrations in μg/g unless otherwise noted)	CAL CRITER se noted)	¥.				
	Ra	Range							ę				
			2	Frequency of Exceedance	avo	Frequency of Exceedance		Frequency	NOAA	Frequency of Exceedance		Frequency	Exceeds
Chemical	Min.	Max.	Guidelines Lowest Effect ^a	Guidelines Lowest Effect	Guidelines Severe Effect ^a	Guidelines Severe Effect	WDNR Guidelines ^c	Exceedance of WDNR Guidelines	ER-L Concen- trations ^e	of NOAA/ER-L Guidelines	USEPA Criteria ^f	Exceedance of USEPA Guidelines	Ecological Risk Criteria
Metals													
Antimony	1.72	1.72	NA	NA	NA	NA	AN	NA	2	0/3	NA	NA	No
Arsenic	3.01	37.4	9	2/3	36	1/3	10	1/3	33	1/3	NA	NA .	Yes
Barium	17.1	72.9	NA	NA	NA	NA	200	0/3	NA	NA	AN	NA	No
Beryllium	0.217	1.09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	2.50	2.50	9.0	1/3	10	0/3	1	1/3	5	0/3	NA	NA	Yes
Chromium	16.5	10.1	26	0/3	110	0/3	100	0/3	80	0/3	AN	NA	No
Cobalt	3.56	25.3	90	0/3	NA	NA	NA	NA	NA	NA	NA	NA	No
Copper	4.25	15.4	91	6/0	110	0/3	100	0/3	70	0/3	NA	NA	No
Iron	5,070	26,500	20,000	1/3	40,000	0/3	NA	NA	NA	V	NA	NA	Yes
Lead	3.22	39.2	31	1/3	250	0/3	50	0/3	35	1/3	NA	NA	Yes
Manganese	115	1,680	460	1/3	1,100	1/3	NA	NA	NA	Y.	NA	NA	Yes
Nickel	6.5	20.7	16	1/3	75	0/3	100	0/3	30	0/3	NA	NA	Yes
Selenium	0.852	0.852	AN	NA	NA	NA	1	0/3	NA	Y.	NA	NA	No
Vanadium	6.5	21.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	32.6	72.9	120	0/3	820	0/3	100	0/3	120	0/3	NA	NA	No
Pesticides													
Heptachlor epoxide	0.114	0.114	0.005	1/3	5 (μg/g OC) ^b	0/3	NA	NA	NA	NA	NA	NA	Yes
alpha-BHC	0.027	0.027	900.0	1/3	10 (μg/g OC) ^b	0/3	0.05	0/3	NA	NA	NA	NA	Yes
gamma- chlordane	0.190	0.190	0.007	1/3	6 (μg/g OC) ^b	0/3	0.01	1/3	0.0005	1/3	NA	NA NA	Yes
Endosulfan, B	0.001	0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Key at end of table.

Table 7-3

(Concentrations in µg/g unless otherwise noted)

ape	Ra	Range											
Chemical	Min.	Max.	OME Guidelines Lowest Effect ^a	Frequency of Exceedance of OME Guidelines Lowest Effect	OME Guidelines Severe Effect ^a	Frequency of Exceedance of OME Guidelines Severe Effect	WDNR Guidelines [¢]	Frequency of Exceedance of WDNR Guidelines	NOAA/ ER-L Concen- trations ^e	Frequency of Exceedance of NOAA/ER-L Guidelines	USEPA Criteria ^f	Frequency of Exceedance of USEPA Guidelines	Exceeds Ecological Risk Criteria
Endrin	0.024	0.024	0.003	1/3	130 (µg/g OC) ^b	0/3	0.05	0/3	0.00002	1/3	4.22 (µg/g OC)	0/3	Yes
p,p'-DDE	0.097	0.345	0.005	2/3	19 (µg/g OC) ^b	0/3	NA	NA	0.002	2/3	NA	NA	Yes
Semivolatile Organics	anics												
Fluoranthene	0.290	0.29	0.750	0/3	1,020 (µg/g OC) ^b	0/3	1,216 (µg/g OC) ^d	6/0	9.0	0/3	620 (µg/g OC)	0/3	No
Pyrene	0.310	0.310	0.490	0/3	850 (µg/g OC) ^b	0/3	NA	NA	0.35	0/3	NA	NA	No
Other Organics													
Total Petroleum Hydrocarbons	174	174	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA NA	NA
Volatile Organics	16												
Toluene	0.030	0.030	NA	NA	VN	NA	NA	NA	NA	NA	NA	NA	NA

^a From: Persaud 1993. Values shown are the lowest effect levels (a level of sediment contamination that can be tolerated by most benthic organisms) or severe-effect levels (a value of contaminant concentration that would be detrimental to the majority of benthic species), as determined by the Ontario Ministry of the Environment.

From: Persaud 1993. Values shown are the severe-effect level normalized for organic carbon (OC).

Bennett, J. and J. Cubbage, 1991. Values shown are background concentrations estimated by the Wisconsin Department of Natural Resources. C From: B

From: Bennett, J. and J. Cubbage, 1991. Values shown are background concentrations estimated by Wisconsin Department of Natural Resources, normalized for organic carbon (OC).

E From: Long E.R. and L.G. Morgan, 1991. Values shown are the Effects Range Low (ER-L), defined as the lower 10 percentile of concentrations observed or predicted to be associated with biological effects. Note that the data used to estimate ER-L are principally from marine and estuarine environments.

f From: USEPA 1993b. Values shown are derived from water criteria using the equilibrium partitioning approach, and normalized for organic carbon (OC).

g Only metals exceeding backgroundare shown.

Key:

NA = Not available.

National Oceanic and Atmospheric Administration. NOAA =

The Ontario Ministry of the Environment. OME

Wisconsin Department of Natural Resources

11:UC6101/RC1275_V3-04/03/95-D2

Table 7-4

SEDIMENTS COMPARISON TO REGIONAL BACKGROUND SITE A12/P36/P37
(μg/g)

Chemical ^a	Site A12/P36/P37 ^b	Ministers Pond	New England Lakes ^c	Massachusetts ^d
Antimony	1.72	ND	3.0	NA
Arsenic	37.4	4.28	13	25
Barium	72.9	39.1	282	NA
Beryllium	1.09	ND	. 7.8	NA
Cadmium	2.50	0.836	3.0	5
Chromium	10.1	9.17	30	30
Cobalt	25.3	5.80	5.4	NA
Copper	15.4	7.45	20	70
Iron	26,500	7,663	71,800	30,000
Lead	39.2	29	310	200
Manganese	1,680	46.4	4,930	350
Nickel	20.7	14.8	11	35
Selenium	0.852	ND	4.6	NA-
Vanadium	21.8	12.0	142	60
Zinc	, 72.9	36.8	. 400	250

^a Only metals exceeding site-specific background or ecological criteria are shown.

NA = Not available.

b Values shown are the maximum detected concentrations in sediments, Site A12/P36/P37.

^C Values shown are the maximum of the range of concentrations reported for remote New England lakes.

d Values shown are levels considered normal in Massachusetts lakes and ponds (from Rojko 1990).

		Table 7-5		
SUMMAF	SUMMARY OF SEDIMENT CONTAMINANTS NORMALIZED FOR ORGANIC CARBON	CONTAMINANTS N	ORMALIZED FOR C	ORGANIC CARBON
Analyte	Sample Number ^a	Concentration (µg/g)	Total Organic Carbon (µg/g) ^b	Organic Carbon Normalized Severe Effect Level ^c (μg/g)
DDE	E3-P37-D01	0.097	254,000	1.9
	E3-P37-D02	0.007	10,800	0.21
	E3-P37-D03	0.345	372,000	1.9
Fluoranthene	E3-P37-D03	0.290	372,000	102
Pyrene	E3-P37-D03	0.310	372,000	85

 a  Only samples with concentrations above the detection limit are shown.  b  Maximum TOC multiplier is 10% (100,000  $\mu g/g)$ .

DDE =  $19 \mu g/g$  OC fluoranthene =  $1,020 \mu g/g$  pyrene =  $850 \mu g/g$ 

^c Organic carbon normalized severe effect level is equal to the criterion in units of  $\mu g/g$  OC * fraction OC. The criteria of the Ontario Ministry of Environment are as follows:

				Table 7-6			
	<b>S</b>	URFACE SO	OILS COMPA SIT	SURFACE SOILS COMPARISON TO ECOLOGICAL CRITERIA SITE A12/P36/P37 (µg/g)	SICAL CRITERI	Ą	
	Ra	Range					
Chemical	Minimum	Maximum	Lower Phytotoxicity Value ^a	Frequency of Exceedance of Lower Reference Value	Upper Phytotoxicity Reference Value ^a	Frequency of Exceedance of Upper Reference Value	Exceeds Ecological Risk Criteria
Metals ^b							
Aluminum	5,390	14,000	NA	NA	NA	NA	NA
Antimony	1.01	5.74	5	1/18	10	0/18	Yes
Arsenic	5.52	14.0	15	0/18	50	0/18	No
Barium	9.62	200	NA	NA	NA	NA	NA
Beryllium	0.147	0.581	10	0/18	10	0/18	No
Cadmium	1.38	15.3	3	4/18	00	1/18	Yes
Chromium	9.34	73.3	50	1/18	100	0/18	Yes
Cobalt	4.84	21.1	25	0/18	50	0/18	No
Copper	6.82	94.35	09	2/18	125	0/18	Yes
Iron	7,480	000'99	NA	NA	NA	NA	NA
Lead	7.60	260	100	1/18	400	0/18	Yes
Manganese	105	346.5	1,500	0/18	3,000	0/18	No
Nickel	9.02	43.6	100	0/18	100	0/18	NA
Thallium	0.149	0.149	1	0/18	1	0/18	No

Key at end of table.

II: UC6101/RC1275-V3-04/03/95-D2

				Table 7-6	100		
,	S	SURFACE SC	ILS COMPA SIT	ACE SOILS COMPARISON TO ECOLOGICAL CRITERIA SITE A12/P36/P37	SICAL CRITERI	Ą	
	Range	96		ò			
			Lower	Frequency of	Upper Phytotoxicity	Frequency of Exceedance of Upper	Exceeds Ecological
Chemical	Minimum	Maximum	Value	Reference Value	Reference Value ^a	Reference Value	Risk Criteria
Vanadium	10.6	36.3	50	0/18	150	0/18 No	No
Zinc	23.1	2,300	70	15/18	400	8/18 Yes	Yes

^a From: Kabata-Pendias and Pendias 1992. Values are minimum or maximum of the range of concentrations regarded as phytotoxic by various authors.
^b Only metals exceeding background are shown.

Key:

NA = Not available.

Chemical   Minimum   Maximum   Minimum   Min					Table 7-7			
Chemical         Minimum         Lower Maximum         Frequency of Value ^a Frequency of Phytotoxicity Phytotoxicity Phytotoxicity Phytotoxicity Phytotoxicity Packedance of Upper Reference Value         Frequency of Phytotoxicity Phytotoxicity Reference Value         Frequency of Phytotoxicity Reference Value         Frequency of Phytotoxicity Packedance of Upper Reference Value         Frequency of Phytotoxicity Phytotoxicity Packedance of Upper Reference Value         Frequency of Phytotoxicity Packedance of Upper Reference Value         Frequency of Phytotoxicity Packedance of Upper Reference Value         Frequency of Phytotoxicity Packed Packedance of Upper Reference Value         Frequency of Phytotoxicity Packed Packedance of Upper Reference Value         Frequency of Phytotoxicity Packed Packedance of Upper Reference Value         Frequency of Upper Reference Value         Frequency of Phytotoxicity Packed Packedance of Upper Reference Value         Frequency of Upper Reference Value         Frequency of Upper Reference Value         Frequency of Upper Reference Value         Frequence of Upper Reference Value         Frequence of Upper Reference Value         NA         NA <t< th=""><th></th><th>SUB</th><th>SURFACE</th><th>SOILS COMI</th><th>ARISON TO ECOL Έ A12/P36/P37 (μg/g)</th><th>OGICAL CRITE</th><th>RIA</th><th></th></t<>		SUB	SURFACE	SOILS COMI	ARISON TO ECOL Έ A12/P36/P37 (μg/g)	OGICAL CRITE	RIA	
Chemical Information         Minimum Maximum Palue ^a Phytotoxicity Value ^a Reference of Lower Phytotoxicity Value ^a Reference Value         Frequency of Phytotoxicity Recedence of Lower Phytotoxicity Reference Value Reference		Rai	nge					
ligh         NA         N	Chemical	Minimum	Maximum	Lower Phytotoxicity Value ^a	Frequency of Exceedance of Lower Reference Value	Upper Phytotoxicity Reference Value ^a	Frequency of Exceedance of Upper Reference Value	Exceeds Ecological Risk Criteria
imm         3,700         11,000         NA         NA         NA         NA         NA           Illium         16         47.5         NA         NA         NA         NA         NA           Illium         6.189         0.473         10         0/15         10         0/15         0/15         10         0/15         0/15         1/16         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/15         0/1	Metals ^b							
imm         16         47.5         NA         NA         NA         NA         NA           llium         0.189         0.473         10         0/15         10         0/15           nium         0.336         64.3         3         2/15         8         1/15           mium         8.14         19.2         75         75         75         1/15         8         1/15           lt         3.82         7.77         25         0/15         50         0/15         50         0/15           er         5.21         17.8         60         0/15         NA         NA         NA         NA           ganese         67.50         15,000         NA         1,500         NA         NA         NA         NA           el         6.60         19.8         10         0/15         10         0/15         10         0/15           el         6.08         19.8         10         0/15         10         0/15         0/15         0/15	Aluminum	3,700	11,000	NA	NA	NA	NA	NA .
Ilium         0.189         0.473         10         0/15         10         0/15           nium         0.336         64.3         3         2/15         8         1/15           mium         8.14         19.2         75         0/15         8         1/15           lt         3.82         7.77         25         0/15         50         0/15           er         5.21         17.8         60         0/15         NA         NA           ganese         65.50         15,000         NA         NA         NA         NA           ganese         67.4         163         1,500         0/15         0/15         0/15           el         6.08         19.8         100         0/15         0/15         0/15	Barium	16	47.5	NA	NA	NA	NA	NA
nium         0.336         64.3         3         2/15         8         1/15           mium         8.14         19.2         75         6.15         100         100         1/15           lit         3.82         7.77         25         0/15         50         0/15         0/15           er         5.21         17.8         60         0/15         NA         NA         NA           ganese         65.50         15,000         NA         1,500         0/15         0/15         0/15           el         66.50         15.00         NA         NA         NA         NA           ganese         67.4         16.3         1,500         0/15         0/15         0/15           el         6.08         19.8         100         2/15         400         0/15	Beryllium	0.189	0.473	10	0/15	10	0/15	No
mium         8.14         19.2         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         75         <	Cadmium	0.336	64.3	3	2/15	8	1/15	Yes
lit         3.82         7.77         25         0/15         50/15         50/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15         6/15	Chromium	8.14	19.2	75	0/15	100	0/15	No
eer         5.21         17.8         60         0/15         125         0/15           ganese         6,500         15,000         NA         NA         NA         NA           el         6,500         15,000         NA         NA         NA           el         67.4         163         1,500         0/15         3,000         0/15           el         6.08         19.8         100         0/15         100         0/15           el         13.2         150         70         2/15         400         0/15	Cobalt	3.82	77.7	25	0/15	50	0/15	No
ganese         6,500         15,000         NA         NA         NA         NA         NA           e1         67.4         163         1,500         0/15         3,000         0/15           e1         6.08         19.8         100         0/15         100         0/15           e1         13.2         150         70         2/15         400         0/15	Copper	5.21	17.8	09	0/15	125	0/15	No
ganese         67.4         163         1,500         0/15         3,000         0/15           el         6.08         19.8         100         0/15         100         0/15           13.2         150         70         2/15         400         0/15	Iron	6,500	15,000	NA	NA	NA	NA	NA
el 6.08 19.8 100 0/15 100 0/15 100 0/15 13.2 150 70 2/15 400 0/15	Manganese	67.4	163	1,500	0/15	3,000	0/15	No
13.2 150 70 2/15 400 0/15	Nickel	80.9	19.8	100	0/15	100	0/15	No
	Zinc	13.2	150	70	2/15	400	0/15	Yes

^a From: Kabata-Pendias and Pendias 1992. Values are minimum or maximum of the range of concentrations regarded as phytotoxic by various authors. b Only metals exceeding background are shown.

NA = Not available.

			Table 7-8				
	GROUNI	OWATER COM DOWNGRAI	TPARISON TO EC DIENT WELLS (UI SITE A12/P36/P37 (#g/L)	GROUNDWATER COMPARISON TO ECOLOGICAL CRITERIA DOWNGRADIENT WELLS (UNFILTERED) SITE A12/P36/P37 (#g/L)	CRITERIA )		
	Range	ıge					
			EPA Ambient Water Quality Chronic	Frequency of Exceedance of	EPA Ambient Water Quality Acute	Frequency of	Exceeds Ecological
Chemical	Minimum	Maximum	Criteriaa	Chronic AWQC	Criteriaa	Acute AWQC	Risk Criteria
Metals ^b							
Arsenic	1.84	100	190c	0/10	360°	0/10	0N
Lead	2.07	29.8	06.0	10/10	23.2 ^d	1/10	Yes
Zinc	25.4	282	45.9 ^d	6/10	50.7 ^d	6/10	Yes
Other Organics							
Total Petroleum Hydrocarbons	1,290	1,930	NA	NA	NA	NA	NA

a U.S. Environmental Protection Agency 1986d, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless otherwise noted.

b Only metals exceeding background are shown.

^C The value is for Arsenic III.

d Hardness-dependent criteria. 37.25mg/L hardness used.

Key:

AWQC = Ambient Water Quality Criteria. NA = Not available.

			Ta	Table 7-9			
		GROUNDWA	GROUNDWATER COMPARISON TO ECOLOGICAL CRITERIA DOWNGRADIENT WELLS (FILTERED) SITE A12/P36/P37	PARISON TO ECOLOC DIENT WELLS (FILTH SITE A12/P36/P37	SICAL CRITERL (RED)	A	
				(µg/L)			
	R	Range		27			
			EPA Ambient	Frequency of	EPA Ambient	Frequency of	Exceeds
Chemical	Minimum	Maximum	Chronic Criteria	Chronic AWQC	Acute Criteria	Acute AWQC	Risk Criteria
Metals ^b							
Manganese	20.1	224	NA	NA	NA	NA	NA
Zinc	71.9	71.9	19.7c	1/12	21.8	1/12	Yes

^a U.S. Environmental Protection Agency 1986, as updated. Values are the freshwater acute and chronic criteria for the protection of aquatic life unless

AWQC = Ambient Water Quality Criteria. NA = Not available.

otherwise noted. b Only metals exceeding background are shown.

c Hardness-dependent criteria. 33.3 mg/L hardness used.

## Table 7-10 CHEMICALS OF POTENTIAL ECOLOGICAL CONCERN SITE A12/P36/P37

Chemical	Surface Water	Sediment	Surface Soil
Metals			
Arsenic	_	X	_
Cadmium	_	_	х
Copper	_	_	х
Lead	х	_	X
Zinc	х	_	х
PCBs			
Aroclor 1260	_	_	х

Key:

X = Selected as a COPC for the ecological risk assessment.

### **Table 7-11**

## AQUATIC HABITAT ASSESSMENT ENDPOINTS A12/P36/P37 SITE

		Assessment Endpoints	
Considerations for Selection of Assessment Endpoints	Aquatic Invertebrates	Semi-aquatic Herbivore-meadow Vole (Microtus pennsylvanicus)	Semi-aquatic Predator/ Raccoon (Procyon lotor)
Ecological relevance	Base of the aquatic food chain.	Herbivore: feeds on aquatic and wetland vegetation. Important food item for higher trophic levels.	Carnivore with an omnivorous diet: feeds on worms, insects, frogs, fish, small mammals, carrion, and plants.
Regulatory and social significance	Water and sediment quality criteria are frequently based on toxicity testing of aquatic invertebrates.	None	Important fur-bearing animal.
Measurability or predictability	Levels of contaminants in sediments and surface water were measured and can be related to toxicity benchmarks derived from regulatory criteria or literature.	Levels of contaminants in sediment and surface water well measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from literature	Levels of contaminants in soil, sediment, and surface water were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.
Susceptibility to COPCs	Aquatic invertebrates are sensitive indicators of surface water or sediment contamination.	Vulnerable to exposure through food chain, direct contact (i.e., burrowing), or through ingestion of water and sediment.	Vulnerable to exposure to COPCs through food chain, also through ingestion or contact with surface water, sediment, and soil.

			Carnivore/Red Fox (Vulpes vulpes)	Omnivore: feeds on small mammals, birds, turtles, insects, and some plants/fruits.	Important fur-bearing mammal.	Levels of contaminants in soils were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Vulnerable to exposure to COPCs through food chain.
	T ENDPOINTS	Endpoints	Songbird/ American Robin (Jurdus migratorious)	Omnivore: feeds on insects, earthworms, and fruits.	Familiar migrating bird in residential areas.	Levels of contaminants in soil were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Vulnerable to exposure to COPCs through food chain, or through ingestion of soil.
Table 7-12	TERRESTRIAL HABITAT ASSESSMENT ENDPOINTS A12/P36/P37 SITE	Assessment Endpoints	Small Mammal/ White-footed mouse (Peromyscus leucopus)	Omnivore: feeds on seeds, fruit, plants, insects, and carrion. Important food item for higher trophic levels.	None.	Levels of contaminants in soils were measured. Levels of contaminants in food items can be measured or predicted and related to toxicity benchmarks derived from the literature.	Vulnerable to exposure through food chain, direct contact (i.e., burrowing), or through soil ingestion.
	TERRESTRIAL		Herbaceous Vegetation	Native grass and forb species provide food and cover for wildlife; reduce erosion in grassland habitats.	None.	Levels of contaminants in soils were measured. These levels can be related to toxicity benchmarks derived from the literature	Vulnerable to exposure through root uptake.
			Considerations for Selection of Assessment Endpoints	Ecological relevance	Regulatory and social significance	Measurability or predictability	Susceptibility to COPCs

			<b>Table 7-13</b>			
	EXP	OSURE POINT	r concentrativ A12/P36/P37 SITE	EXPOSURE POINT CONCENTRATIONS FOR COPCS A12/P36/P37 SITE	OPCS	
	Surface	Surface Water	Sediment	nent	Surface Soil	e Soil
Chemical	Average Concentration (µg/L)	Maximum Concentration (µg/L)	Average Concentration (µg/g)	Maximum Concentration (μg/g)	Average Concentration (µg/g)	Maximum Concentration (µg/g)
Metals						
Arsenic	NC	NC	16.4	37.4	NC	NC
Cadmium	NC	NC	NC	NC	2.5	15.3
Copper	NC	NC	NC	NC	23.8	91.4
Lead	12.4	23.2	NC	NC	42.9	260
Zinc	20.4	46.5	NC	NC	527	2,300
PCBs						
Aroclor 1260	NC	NC	NC	NC	0.83	4.7

Key:

NC = Not a COPC; therefore, exposure point concentrations were not calculated.

				Tabl	Table 7-14					
			EXPOSUR	E PARAME A12/P36	ARAMETERS FO A12/P36/P37 SITE	EXPOSURE PARAMETERS FOR WILDLIFE A12/P36/P37 SITE		,		
		Percent of Diet	- Terrestrial	of Diet - Terrestrial Food Chain ^a		Pe	Percent of Diet - Aquatic Food Chain ^a	quatic Food	Chaina	
Receptor	Plants	Invertebrates	Birds	Mammals	Soil	Macrophytes	Invertebrates	Herptiles	Fish	Sediment
Meadow Vole	-	1	1	-	1	%66	1%	1	1	2%
Raccoon	42%	32%	1	2%	4%	_	14%	%5	2%	4%
American Robin	62%	38%	1	1	10%	1	1	1	1	1
White-footed Mouse	54%	46%	1	1	2%	1	1	1	1	ı
Red Fox	18%	4%	14%	64%	3%	_	-	1	1	1

0.	EXP	OSURE PAR	Table 7-14 AMETERS	Table 7-14 EXPOSURE PARAMETERS FOR WILDLIFE	FE	
		A12	A12/P36/P37 SITE	TE		
Receptor	Home Range (acres) ^a	Site Use Factor ^b	Exposure Duration ^c	Drinking Rate (L/day) ^a	Ingestion Rate (kg/day) ^a	Body Weight (kg) ^a
Meadow Vole	0.23	1	1	0.00763	0.00473	0.037
Raccoon	129	0.107	1	0.581	0.3402	7
American Robin	0.52	1	99.0	0.01078	0.01597	7.000
White-footed Mouse	0.54	1	1	0.00361	0.00327	0.019
Red Fox	124	0.111	1	0.3995	0.24521	4.7

a USEPA 1993c. b Site Use Factor = site area (upland = 13.8 acres; wetland = 4.6 acres) divided by home range (acres). c Exposure Duration = fraction of year spent in region.

	¥	ertebrates	Tissue Level (mg/kg) ^a	0.131	1.51	33.3
	10	Fish, Herptiles, and Benthic Invertebrates	Exposure Medium	SED	SW	SW
	ESTIMATED TISSUE LEVELS IN AQUATIC SPECIES AVERAGE EXPOSURE CASE A12/P36/P37 SITE	Fish, Herp	BAF ^a	0.008	122	1,633
<b>Table 7-15</b>	AVERAGE EXPOSURE CASE A12/P36/P37 SITE		Tissue Level (mg/kg) ^a	99.0	1.04	5.71
	STIMATED TISSU  AVERA	Macrophytes	Exposure Medium	SED	SW	SW
	3		Plant Uptake Factor ^a	0.04 SED	84	280
			Chemical	Arsenic	Lead	Zinc

^a Dry-weight basis. See Volume 1, Section 5 for method of calculation.

BAF = Bioaccumulation Factor. SED = Sediment. SW = Surface water.

ESTIMATED TISSUE LEVELS IN TERRESTRIAL SPECIES           AVERAGE EXPOSURE CASE         AVERAGE EXPOSURE CASE           Chemical Cadmium         Terrestrial Plants         Terrestrial Invertebrates         BAFa         Ring/kg)         BAFa         Tissue Level (mg/kg)         Ring/kg)         Ring/kg)         Ring/kg)         BAFa         Tissue Level (mg/kg)         Tissue Level (mg/kg)         Tissue Level (mg/kg)         Ring/kg)         Ring/k					<b>Table 7-16</b>				
real         Flant Uptake         Tissue Level (mg/kg) ^a BAFa         Tissue Level (mg/kg) ^a BAFa         Tissue Level (mg/kg)         Tissue Level (mg/kg)         Tissue Level (mg/kg)         BAFa         Tissue Level (mg/kg)			ESTIMA	TED TISSUE   AVERA A	LEVELS IN TE GE EXPOSURI 12/P36/P37 SIT	RRESTRIAL S CASE	PECIES		
Plant Uptake Factor ^a Name         Tissue Level Factor ^a (mg/kg) ^a BAF ^a (mg/kg) ^a Tissue Level (mg/kg) ^a BAF ^a (mg/kg) ^a Plant Uptake         Plant Uptake		Terrestri	al Plants	Terrestrial I	nvertebrates	Bir	qs	Small Ma	ammals
n         0.55         1.375         0.31         0.775         0.017         0.043         0.03           0         0.40         9.52         0.48         11.4         0.0038         0.09         0.10           0         0.045         1.93         0.0081         0.35         0.0073         0.31         0.0135           1260         .0015         0.0012         0.0012         0.0012         0.0061         0.0061         0.0061         0.0061         0.0061	Chemical	Plant Uptake Factor ^a	Tissue Level (mg/kg) ^a	BAF ^a	Tissue Level (mg/kg) ^a	BAF ^a	Tissue Level (mg/kg)	BAF ^a	Tissue Level (mg/kg)
1260         0.040         9.52         0.048         11.4         0.0038         0.09         0.09         0.013           1260         .0015         0.0012         0.0012         0.0012         0.0012         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.0061         0.00	Cadmium	0.55	1.375	0.31	0.775	0.017	0.043	0.39	86.0
1260         .0015         0.0015         0.0015         0.0015         0.0015         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001         0.0001 <td>Copper</td> <td>0.40</td> <td>9.52</td> <td>0.48</td> <td>11.4</td> <td>0.0038</td> <td>0.00</td> <td>0.10</td> <td>2.38</td>	Copper	0.40	9.52	0.48	11.4	0.0038	0.00	0.10	2.38
1.5         790         2.1         1,107         0.90         474         2.31           10x 1260         .0015         0.0015         0.0012         0.0061         0.0061         0.0061         0.0061	Lead	0.045	1.93	0.0081	0.35	0.0073	0.31	0.0135	0.58
.0015 0.0012 0.0015 0.0012 0.0061 0.0061 0.0061 0.0061	Zinc	1.5	790	2.1	1,107	06.0	474	2.31	1,217
	Aroclor 1260	5100.	0.0012	0.0015	0.0012	0.0061	.0051	0.0061	.0051

^a Dry weight basis. See Volume 1 Section 5 for method of calculation. All factors calculated using soil as the exposure medium.

BAF = Bioaccumulation factor.

			<b>Table 7-17</b>			
×	A	STIMATED TISS	ESTIMATED TISSUE LEVELS IN AQUATIC SPECIES	QUATIC SPECIES	70	
		1	RME CASE A12/P36/P37 SITE			
		Macrophytes		Fish, Herp	Fish, Herptiles, and Benthic Invertebrates	rtebrates
Chemical	Plant Uptake Factor ^a	Exposure Medium	Tissue Level (mg/kg) ^a	BAFª	Exposure Medium	Tissue Level (mg/kg) ^a
Arsenic	0.04	SED	1.50	0.008	SED	0:30
Lead	84	SW	1.95	122	SW	2.83
Zinc	280	SW	13.02	1,633	SW	75.93

^a Dry-weight basis. See Volume 1, Section 5 for method of calculation.

BAF = Bioaccumulation Factor. SED = Sediment. SW = Surface water.

				<b>Table 7-18</b>				
		ESTIMAT	ED TISSUE I	LEVELS IN TER RME CASE A12/P36/P37 SITE	TIMATED TISSUE LEVELS IN TERRESTRIAL SPECIES RME CASE A12/P36/P37 SITE	SPECIES		
	Terrestri	Terrestrial Plants	Terrestrial Invertebrates	nvertebrates	Bir	Birds	Small Mammals	ammals
Chemical	Plant Uptake Factor ^a	Tissue Level (mg/kg) ^a	BAFª	Tissue Level (mg/kg) ^a	$BAF^a$	Tissue Level (mg/kg) ^a	$ m BAF^a$	Tissue Level (mg/kg) ^a
Cadmium	0.55	8.41	0.31	4.74	0.017	0.26	0.39	5.97
Copper	0.40	36.6	0.48	43.9	0.0038	0.35	0.10	9.14
Lead	0.045	11.7	0.0081	2.11	0.0073	1.90	0.0135	3.51
Zinc	1.5	3,450	2.1	4,830	0.90	2,070	2.31	5,313
Aroclor 1260	0.0015	.0071	0.0015	.0071	0.0061	0.029	0.0061	0.029

^a Dry weight basis. See Volume 1, Section 5 for method of calculation. All factors calculated using soil as the exposure medium.

BAF = Bioaccumulation factor.

## **Table 7-19**

## ESTIMATED EXPOSURES (EE) FOR WILDLIFE SITE A12/P36/P37

		Estimated Exposur	e (mg/kg/d) ^a
Chemical	Endpoint Species	Average Case	RME Case
Arsenic	American Robin	NC	NC
	Meadow Vole	0.125	0.285
	Raccoon	0.0036	0.0081
	Red Fox	NC	NC
	White-footed Mouse	NC	NC
Cadmium	American Robin	0.19	1.2
	Meadow Vole	NC	NC
	Raccoon	0.0051	0.031
	Red Fox	0.0057	0.035
	White-footed Mouse	0.20	1.2
Copper	American Robin	1.7	6.6
	Meadow Vole	NC	NO
	Raccoon	0.045	0.17
	Red Fox	0.026	0.099
	White-footed Mouse	1.9	7.2
Lead	American Robin	0.77	4.
	Meadow Vole	0.14	0.20
	Raccoon	0.016	0.08
	Red Fox	0.012	0.073
	White-footed Mouse	0.36	2.:
Zinc	American Robin	130	570
	Meadow Vole	0.77	1.5
	Raccoon	4.0	1
	Red Fox	6.1	2
	White-footed Mouse	160	71
Aroclor 1260	American Robin	0.012	0.06
	Meadow Vole	NC	N
	Raccoon	0.00018	0.001
	Red Fox	0.00017	0.0009
	White-footed Mouse	0.0031	0.01

a See Volume I, Section 5 for method of calculation.

Key:

NC = Not a COPC, value not calculated.

Table 7-20					
TOXICITY REFERENCE VALUES (TRVs) FOR WILDLIFE SITE A12/P36/P37					

Chemical	Endpoint Species	NOAEL (mg/kg/d) ^a
Arsenic	American Robin	2.12
	Meadow Vole	0.11
	Raccoon	0.021
	Red Fox	0.024
	White-footed Mouse	0.14
Cadmium	American Robin	3.542
	Meadow Vole	0.169
	Raccoon	0.031
	Red Fox	0.037
	White-footed Mouse	0.212
Copper	American Robin	62.9
	Meadow Vole	32.8
	Raccoon	6.16
	Red Fox	7.13
	White-footed Mouse	41.3
Lead	American Robin	4.58
	Meadow Vole	15.9
	Raccoon	2.98
	Red Fox	3.44
9	White-footed Mouse	19.9
Zinc	American Robin	410
	Meadow Vole	317
	Raccoon	59.5
	Red Fox	68.9
	White-footed Mouse	399
Aroclor 1260	American Robin	3.82
	Meadow Vole	NC
	Raccoon	0.07
¥	Red Fox	0.07
	White-footed Mouse	0.22

^a Opresko *et al.*, 1994 for NOAELs; raccoon NOAEL based on the formula provided in Volume I, Section 5 (body weight from USEPA 1993f).

Table 7-21
SUMMARY OF HAZARD QUOTIENTS FOR WILDLIFE
SITE A12/P36/P37

		Hazard Quotient ^a		
Chemical	Endpoint Species	Average Case	RME Case	
Arsenic	American Robin	NC	NC	
	Meadow Vole	1.1	2.6	
	Raccoon	0.2	0.4	
	Red Fox	NC	NC	
	White-footed Mouse	NC	NC	
Cadmium	American Robin	0.05	0.3	
	Meadow Vole	NC	NC	
	Raccoon	0.2	1.0	
	Red Fox	0.2	0.9	
	White-footed Mouse	0.9	5.7	
Copper	American Robin	0.03	0.1	
	Meadow Vole	NC	· NC	
	Raccoon	0.007	0.03	
	Red Fox	0.004	0.01	
	White-footed Mouse	0.04	0.2	
Lead	American Robin	0.2	1.0	
	Meadow Vole	0.009	0.02	
	Raccoon	0.005	0.03	
	Red Fox	0.004	0.02	
	White-footed Mouse	0.02	0.1	
Zinc	American Robin	0.3	1.4	
2	Meadow Vole	0.002	0.006	
	Raccoon	0.07	0.3	
	Red Fox	0.09	0.4	
	White-footed Mouse	0.4	1.8	
Aroclor 1260	American Robin	0.003	0.02	
	Meadow Vole	NC	NC	
	Raccoon	0.003	0.01	
	Red Fox	0.002	0.01	
	White-footed Mouse	0.01	0.08	

^a See Volume I, Section 5 for method of calculation. See Table 7-18 for Estimated Exposures, Table 7-19 for Toxicity Reference Values.

## SUMMARY OF HAZARD QUOTIENTS FOR AQUATIC LIFE SITE A12/P36/P37

**Table 7-22** 

	ar ar	Hazard Quotient ^a	
Chemical	Endpoint Species	Average Case	RME Case
Arsenic	Aquatic invertebrates - water column	, NC	NC
	Benthic invertebrates	0.5	1.1
Lead	Aquatic invertebrates - water column	. 43	80
	Benthic invertebrates	NC	NC
Zinc	Aquatic invertebrates - water column	1.0	2.2
	Benthic invertebrates	NC	NC

a See Volume I, Section 5 for method of calculation. See Table 7-12 for Estimated Exposures, Table 7-2 and Table 7-3 and text for Toxicity Reference Values.

Key:

NC = Not a COPC, value not calculated.

# Table 7-23 SUMMARY OF HAZARD QUOTIENTS FOR TERRESTRIAL PLANTS A12/P36/P37 SITE

	Hazard Quo	Hazard Quotient ^a		
Chemical	Average Case	RME Case		
Arsenic	NC	NC		
Cadmium	0.8	5.1		
Copper	0.4	1.5		
Lead	0.1	0.7		
Zinc	7.5	33		

See Volume I, Section 5 for method of calculation. See Table 7-12 for Estimated Exposures; Table 7-5 and text for Toxicity Reference Values.

Key:

NC = Not a COPC, value not calculated.

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### 8. CONCLUSIONS AND RECOMMENDATIONS

Based on the human health risk and ecological risk assessments, no action under CERCLA is warranted at Site A12/P36/P37.

The human health risk assessment for Site A12/P36/P37 concluded that the reasonable maximum exposure (RME) to current site conditions was within the 10⁻⁴ to 10⁻⁶ range of cancer risk primarily due to PCBs in soil and arsenic in sediment, although the arsenic does not originate on site. This is within the range considered acceptable by the EPA. The hazard index (HI) for non-carcinogenic RME risks do not exceed the EPA benchmark value of 1.0.

Under a future residential scenario the estimated cancer risk for RME conditions is greater than 10⁻⁴ by a small margin for both adults and children, although the average exposure and risk is lower by an order of magnitude. The HIs for RMEs under this scenario are greater than 1 only for children, the HI associated with dermal adsorption and ingestion of PCB-1254 being 1.6.

Unfiltered samples of groundwater had cancer risks of greater than 10⁻⁴, due to arsenic content, but filtered groundwater had a maximum reasonable exposure risk of less than 10-4 for both adults and children, and was well below the drinking water maximum contaminant levels (MCLs) for arsenic. Similar results occur for non-carcinogenic risks of groundwater consumption, with unfiltered samples containing suspended sediment having maximum HIs of 10 and 12 for adults and children respectively. Filtered (non-turbid) samples dropped the HIs below 1.0 for both adults and children.

Arsenic levels in site soil and filtered groundwater are only 40 percent greater than those in background soils, and twice the level found in the local background well, respectively. Groundwater at the site is not now used, nor is it likely to be used, because of the low yield of the site aquifer and the availability of a public water supply. The combined RME risks of cancer to adult residents due to exposures to soil and filtered groundwater levels of arsenic is 6.6 x 10⁻⁴. This filtered level of arsenic is well below the current drinking water standard. The metals levels in the groundwater are due to naturally occurring conditions and are not the result of site contamination.

The ecological risk assessment concluded that the contaminants identified at the site did not pose significant risks to populations of plants or wildlife. The maximum detected levels of metals exceeded reference values for animals and plants but the limited extent and disturbed nature of the site means that these levels are not likely to be ecologically significant. Lead and zinc levels in unfiltered surface water samples could potentially adversely affect aquatic life but these are not shown to be site related and average exposures do not appear to represent risks.

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The level of PCBs in surface soils is greater than the EPA recommended screening level of 1.0  $\mu$ g/g in residential areas. It is recommended that before the site is released for unrestricted use, surface soils be cleaned up to meet the 1.0  $\mu$ g/g screening level criterion. This can be done by administrative action and does not require a formal CERCLA removal action.

It is recommended that a No Action Proposed Plan be prepared for Site A12/P36/P37.

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